FINAL REPORT

RESEARCH ON HUMPBACK AND BLUE WHALES OFF CALIFORNIA, OREGON AND WASHINGTON IN 2001

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EXECUTIVE SUMMARY

Cascadia Research conducted research on humpback and blue whales off California, Oregon, and Washington in 2001. The primary purpose of the research has been to examine distribution, abundance, movements, and population dynamics of humpback and blue whales in the eastern North Pacific using photographic identification of individual animals.

Photographic identification was primarily conducted from small boats on 63 days of totaling 522 hours on the water. Additional, photo-ID was conducted from SWFSC's ORCAWALE cruise off California, Oregon, and Washington, during surveys based from the Scripps vessel *Sproul*, and opportunistically from whale-watch boats. Suitable identification photographs of blue whales were made on 539 occasions representing 274 unique whales, one of our highest annual totals. Identifications of humpback whales were made on 541 occasions representing 311 unique individuals.

Estimates of humpback whale abundance using a number of mark-recapture models indicated abundance had declined starting in the late 1990s. After a high of just over 1000 whales in the late 1990s, the current estimate shoes a decline to 779 whales. The reduction appears to have occurred as a result of an elevated mortality (or emigration) rate. There has not been any indication of decreased number of calves in the population or increased number of strandings. The cause for this decline is not clear but appears to coincide with the timing of the severe 1997-98 *El Nino*. While the population does not appear to have recovered to pre-whaling numbers, there have been indications of declines in plankton and zooplankton-feeding seabirds off California in the 1980s and 1990s and may be lowering the carrying capacity for humpback whales.

Blue whale abundances could not be accurately estimated from the 2001 samples because relatively few blue whales were encountered and identified during the systematic SWFSC surveys. The identifications from these surveys provide an essential representative sample of blue whales in both inshore and offshore waters. Estimates made using the 2001 data yielded an abundance of only about 1,000 blue whales, well below the numbers estimated obtained from previous surveys. The small number of identifications obtained from the 2001 systematic surveys, however, result in these estimates having a high level of imprecision.

Tagging efforts in 2001 resulted in successful suction-cup attachment of two types of tags on blue whales. Crittercam deployments yielded information on feeding and diving behavior of blue whales off southern California. Data and video images from these deployments of San Miguel and San Nicolas Island showed blue whales feeding down to 300 m on extremely dense layers of krill. Additional short test deployments were made of a new acoustic-recording tag.

INTRODUCTION

This report summarizes the fieldwork conducted by Cascadia Research in 2001 for humpback and blue whales off California, Oregon, and Washington. While the focus of this report is the results from photographic identification, we also summarize some of the findings from related work collecting skin samples and deploying tags on whales. The primary purpose of the photographic identification research has been to examine distribution, abundance, movements, and population dynamics of humpback and blue whales in the eastern North Pacific.

Principal support for this research was from Southwest Fisheries Science Center to assess population size and trends as well as reproductive and mortality rates (Contract # 50ABNF100065). Support for several related projects that allowed additional opportunity to obtain identifications photographs and other types of data came from several additional sources:

- Office of Naval Research provided support for the Crittercam deployments on blue whales (in collaboration with National Geographic) off Mexico and California under grant award No. N00014-00-1-0942.

- Support for some of the work off Southern California was provided through a subcontract from Scripps Institute of Oceanography (Purchase Order 10200451) as part of a project on ambient noise and blue whale vocalizations for the San Clemente Offshore Range (SCOR).

- The National Marine Mammal Laboratory provided partial support for some of the gray whale work in Washington and Oregon under Purchase Order #40BANF112521.

- Several private contributors provided support for conducting the research.

METHODS

Survey regions and coverage

Survey effort using Cascadia small boats is summarized by day in Table 1. There was a total of 63 days of small boat surveys using Cascadia vessels and totaling 522 hours on the water (Table 1). Additionally, Cascadia provided personnel to serve as photo-ID specialists aboard SWFSC's ORCAWALE cruise off California, Oregon, and Washington (Tables 2 and 3). There was also additional opportunistic effort aboard the Scripps vessel *Sproul* (see below). Some opportunistic effort was conducted from whale-watch boats in northern Puget Sound, Grays Harbor, off Oregon, and Monterey Bay (Tables 4). Photographic identification from whale-watch boats was most extensive in Monterey Bay where Peggy Stapp and Nancy Black obtained opportunistic identification photographs from regular trips from late April to the end of October (Table 5). Survey effort was fairly broadly distributed along the west coast (Table 6, Figure 1) and identifications obtained from a broad area and time period (Tables 7-8). Primary locations and descriptions of effort are provided below.

Identifications from ORCAWALE cruises

ORCAWALE cruises were conducted by SWFSC along the coast of California, Oregon, and Washington from 30 July to 7 December 2001 (Tables 2 and 3). Annie Douglas, Todd Chandler, and Paula Olson were aboard different legs to obtain photographic identifications of whales. The primary goal of the photographic identification effort on the cruise was to obtain a representative sample of blue whales from both coastal and offshore waters. Unlike humpback whales that primarily feed along the continental shelf and near the shelf edge, blue whales utilize coastal as well as more offshore waters off the shelf and to not intermix completely between these areas. That makes the unbiased sample from the systematic ship surveys covering waters out to 300 nmi offshore, in conjunction with the larger but coastally-biased sampled obtained in our small boat surveys, critical to obtaining unbiased mark-recapture abundance estimates of blue whales. The small boat was deployed to obtain identification photographs of blue whales on 10 days. A total of 16 blue whales were approached with the small boat and identification photographs obtained of 14 of them.

Photographic identification surveys off California

Photographic identification surveys for humpback and blue whales were conducted off California by Cascadia personnel using Cascadia's two 5.3m RHIBs and on a few occasions a larger boats between 17 April and 9 November 2001 (Table 1). These surveys were generally conducted within 50 nmi of shore. Survey effort was heaviest off Southern California and in the region from Monterey Bay to the Gulf of the Farallones (Table 6) and included:

- Early season surveys in Monterey Bay in April and May 2001.
- Small-boat surveys throughout the southern California Bight area in June and August that were conducted in association with the Scripps surveys based from the *Sproul* (see next section).

- Surveys in July in the Southern California Bight including in the Santa Barbara Channel, around San Nicolas Island, and off San Miguel Island. Some of these surveys were conducted in association with efforts to deploy Crittercam instrument packages on blue whales.
- Surveys from August to October from Monterey Bay to the Gulf of the Farallones, some of which were conducted in association with efforts to deploy and acoustic tag on blue whales.

Surveys conducted on the *Sproul* in collaboration with Scripps Institute of Oceanography

Four surveys were conducted in collaboration with Scripps Institute of Oceanography (SIO) as part of a project on ambient noise and blue whale vocalizations for the San Clemente Offshore Range (SCOR). All four cruises were aboard the *Sproul*, two of them with a Cascadia RHIB aboard which was deployed during the surveys. The four surveys were 28 April to 1 May. 18-26 June, 21-29 August, and 23-25 October 2001. Surveys in June and August were substantially longer than the other cruises, had a Cascadia RHIB on board and included extensive coverage of the Southern California Bight. The shorter cruises were conducted between San Diego and Tanner/Cortez Bank.

Effort off Washington and Oregon

We conducted 10 days of surveys off Washington and Oregon between 19 April and 5 October 2001 (Table 1). We also took advantage of several platforms for opportunistic effort (Table 4). Survey effort included:

- Photographic identification of humpback and gray whales conducted off the northern Washington coast out of La Push including to the British Columbia border on 4 days from 13 September to 5 October 2001.
- Surveys of coastal waters for gray whales including Grays Harbor and some offshore coverage incidental to trips to collect feces of northern sea lions with the Washington Department of Fish and Wildlife on 4 days between 19 April and 6 July 2001.
- Dedicated and opportunistic observations from whale-watch boats were conducted off Oregon out of Depoe Bay and Newport from 6 June to 19 October 2001. Most of the effort was in coastal waters for gray whales but some coverage for humpback whales was also conducted.
- Photographic identification of gray whales was conducted in northern Puget Sound on 15 April 2001. Additional opportunistic observations not under this permit were made from 25 March to 22 April 2001 incidental to whale-watching aboard the *St. Nicholas* (operated by Mosquito Fleet).

Photographic identification methods

Identification photographs were taken with *Nikon* 35mm cameras (8008 and N90s) equipped with 300mm *Nikkor* telephoto lenses and databacks that recorded date/time on the exposed film. High-speed black-and-white film (*Ilford HP-5+*) was exposed pushed 1 stop so that exposure times were generally 1/1,000 or 1/2,000 sec.

Identification photographs of humpback and blue whales were taken using standard procedures employed in past research off California and Washington (Calambokidis *et al.* 1990a, 1990b, 1996, 2000, 2001b). Both the right and left sides of blue whales in the vicinity of the dorsal fin or hump were photographed as well as the ventral surface of the flukes. For humpback whales, photographs were taken of the ventral surface of the flukes.

Humpback and blue whale identification photographs taken in 2001 were compared internally and then to catalogs of all humpback and blue whales identified previously along the west coast. These catalogs consisted of 1,219 different humpback whales and 1,272 different blue whales identified during annual surveys between 1986 and 2000 off the west coast (Calambokidis *et al.* 2001b). Additional identifications included in these collections are whales identified in other areas such as off Central America by Cascadia and collaborators (Rasmussen *et al.* 1999, 2000, Chandler *et al.* 1999). Individual whales identified in 2001 that did not match past years and were of suitable quality were assigned a new unique identification number and added to the catalogs.

Observations were routinely made of the feeding behavior of both humpback and blue whales. A variety of data are also recorded that are related to feeding including surface temperature, water depth, the presence and depths of any scattering layers, and bird species associated with sightings.

Mark-recapture estimates

Estimates of abundance were calculated using several mark-recapture models (Hammond 1986, Seber 1982). We used pairs of adjacent years from annual samples taken from 1991 to 2001 for California, Oregon, and Washington to generate Petersen mark-recapture estimates. The Chapman modification of the Petersen estimate (Seber 1982) was used because it was appropriate for sampling without replacement (Hammond 1986). Abundance estimates were also obtained using the Jolly-Seber multi-year models and annual samples. General assumptions and potential biases for these calculations are discussed in Hammond (1986) and Calambokidis *et al.* (1990a).

In addition to annual samples, we also conducted Petersen mark-recapture estimates using samples stratified by type of survey. To avoid heterogeneity of capture probability due to geographic sampling bias, we used the identifications obtained during systematic surveys conducted by SWFSC covering coastal and offshore waters of Baja California, California, Oregon, and Washington. Identifications from these surveys, although small, provided a sample that was not biased geographically. These systematic samples were paired with the larger but more geographically biased sample obtained during the more extensive coast-based surveys for the same 2 to 3-year periods.

A more conservative method for calculating the variance of Petersen capture-recapture estimates based on the jackknife procedure was employed here. Traditional estimates of variance from capture-recapture estimates may be biased downward because identifications are not independent events. Geographical clumping of animals often resulted in a concentration of

sampling effort in these regions. Other aggregations of animals may have not been seen and not sampled. Although humpback whales often range widely along the coast of California, Oregon, and Washington during the season, animals show a preference to return to similar areas each year. To incorporate the variance introduced by this geographic clumping of whales and sample effort, a jackknife estimate of variance was calculated using entire regions as samples. Each sample was divided into five to nine subsamples based on regions and time period. To obtain similar sample sizes, some adjacent regions were pooled together and some areas of high coverage divided into subsamples by season. For capture-recapture calculations that were based on multi-year samples taken from different platforms (SWFSC vs. other), each platform was divided into five roughly-equal subsamples based on year of sample and broad regions. Pseudovalues for generating the jackknife variance were calculated by excluding each sample from the estimate. Because the Petersen estimate is based on two samples, between 10 and 16 pseudovalues were calculated for each estimate.

Variance was calculated as:

$$VAR = \frac{(n-1)}{n}\sum(P - P_i)^2$$

from Efron (1982) where n is the number of estimates, P_i is each of the abundance estimates calculated by excluding one set of samples, and P is the abundance estimate using all data.

Collection of skin samples

A total of 63 skin samples were collected from four cetacean species in 2001 (Table 9). Most (56) of the samples were collected from blue whales, with the majority of these (40) being biopsies. Additional samples of sloughed skin were collected from tags or the deployment head, and occasionally from the water in the whale’s footprint. Blue whales samples were primarily collected in the Southern California Bight in June and August 2001 in association with Scripps Institute of Oceanography cruises and also in July 2001 in association with Crittercam deployments. The three primary areas samples were collected were around Tanner/Cortez Bank, on the north side of San Nicolas Island, and in the Santa Barbara Channel. For most of these blue whale samples, the vocal behavior of the animal is known either from deployed sonobuoys or from recordings made from the hydrophone on the Crittercam. In at least one case (samples 010824-3&4) the blue whale sampled was a calling whale whose vocal behavior was tracked over an extended period. Skin samples were submitted to SWFSC for gender determination.

A few samples were collected from other species as well. Skin samples were collected by biopsy from two humpback whales near the Washington/British Columbia border. This appears to be near the boundary between distinct humpback whale feeding aggregations and so the mtDNA patterns in these whales is of interest. We have been collecting samples which in recent years and this is the focus of a collaborative proposal with Dr. Scott Baker currently in review. Skin samples were also collected by biopsy of two fin whales in the Southern California Bight

whose vocal behavior was being tracked. Three killer whales were sampled in Monterey Bay that were part of a small transient group we identified.

Skin samples were collected to examine genetic relatedness, population structure, and sex of individual whales (Baker *et al*. 1990, 1998). Biopsy samples were collected from whales using the system developed by Lambertsen (1987). The biopsy system has three integral components: a biopsy dart and punch, a projection unit, and a retrieval system. The biopsy dart consists of a crossbow bolt (arrow) affixed with a stainless steel biopsy punch. The biopsy punch has a flange or 'stop' to prevent penetration of the skin. The punch is 7 to 9 mm in diameter and 2 to 5 cm in length and is fitted with two or three internal pins to secure the sample. A hole drilled transversely through the punch and just distal of the flange prevents pressure buildup inside the punch as it penetrates the skin. The projection unit is a commercially available crossbow fitted with a 125 or 150-lb draw fiberglass prod (bow). Sample extraction occurs with the recoil of the dart when the flange strikes the skin. We used an untethered free-floating bolt retrieved by hand from small vessels or with a dip net from larger vessels.

Tagging

Tagging in 2001 consisted of deployment of two instrument packages on blue whales. The first was an instrument developed by National Geographic and termed “Crittercam”, onto blue whales (Marshall 1998, Williams *et al*. 2000, Francis *et al*. 2001). A suction-cup was used for attachment to blue whales. Attachment was achieved by close approach and attachment using a long pole to make direct contact with the whale. The instrument packages deployed contained a combination of the following instruments and devices:

- Hydrophone and recording system for underwater vocalizations
- Pressure sensor to record water depth
- Sensor to monitor and record water temperature
- Conductivity switch to control surface and underwater instrument activation
- VHF tag to provide local positioning information
- Underwater video camera to record behavior and prey

We also attempted deployment of an acoustic tag on blue whales as part of collaboration with Scripps Institute of Oceanography. The acoustic tag was developed by Bill Burgess of Greeneridge Scientific Services (with support from ONR). We worked with Dr. Burgess, Scripps, and Joe Olson of Cetacean Research to test the tag and develop a housing and delivery method for the tag.

Measurements of the sizes of whales

We also continued to use a method for determining the relative sizes of humpback, blue, and gray whales by measuring the width of the flukes of animals (Calambokidis *et al.* 2001c). In conjunction with identification photographs, the distance to the whale was measured using a *Bushnell Yardage Pro 1000* laser range-finder. The range finder and lens focal-length were calibrated by taking sets of measurement of known size targets on land. The range finder yielded consistent measurements of distance with relatively little error and only a slight bias for which an

adjustment could be made in the calibration equation. Measurements of whales were attempted when directly behind the whale so that the flukes were perpendicular to the photograph angle. When this was not possible, the angle off perpendicular was estimated in the field. The length of the whale was calculated based on regressions of the size of the fluke to the overall length of whales determined from stranded animals.

We obtained an excellent sample of 165 fluke measurements in 2001 off California, Oregon, and Washington (Table 10). This brought our total number of measurements to 302 with 185 or 61% meeting our initial screening criteria for having an adequate measurement and angle (Table 10). The large number of additional measurements obtained in 2001 provided an excellent sample to test the reproducibility of this method and identify sources of variation. Repeat measurements of the same were obtained on 83 occasions involving 30 different whales (Table 11). Multiple measurements of the same whale fell within 5% of the average for that whale 80% of the time (Table 11). Examination of the 20% of the whales that were more than 5% different from the mean revealed that they tended to be taken at more extreme distances (<40 or >80 m) and closer to the limit of our angle cut-off of 15º compared to both the samples that were within 5% of the mean or our sample as a whole (Table 12). These findings indicate that we can obtain greater accuracy in our measurements by being more selective (in terms of acceptable distance or angle) in our criteria.

RESULTS AND DISCUSSION

Humpback whale sightings and identifications from small-boat surveys

Identifications of humpback whales were made on 541 occasions representing 311 unique individuals (Tables 8 and 13). Although identifications were obtained in a broad number of areas, the largest numbers came from central California extending from Monterey Bay to Bodega Bay (Table 6, Figure 2). Identifications were obtained in Monterey Bay early in the season (April and May) and from August to November during both surveys by Cascadia and from whale-watch vessels (Table 6). We also obtained a large number of identifications in the region between Monterey Bay and Half-Moon Bay where humpback whales were concentrated in September and October. We obtained a large number of identifications in the Gulf of the Farallones in August.

Although we identified a small number of humpback whales scattered throughout southern California, we were not able to conduct surveys during a short period in June when humpback whales were reported to be in large numbers in the Santa Barbara Channel feeding on anchovies. Identifications were also made off the northern Washington coast in September and October. We did not encounter humpback whales in several surveys that were conducted off Oregon and northern California.

Sighting of mothers and calves

In 2001, 17 individual humpback whales were observed identified as mothers with calves (including six tentative identifications as animals with calves) and 11 calves were identified photographically (including 4 tentative determinations). Of the 276 humpback whales identified in 2001, 6.2% of whales identified were mothers. This “reproductive rate” is within the range found previously which has been between 4.3 and 8.0% since 1995 (Table 14). Seven of these mothers had been seen with calves previously, including two that have been seen with calves four times (10081 in 1990, 1991, 1993 and 2001; 10243 in 1992, 1994, 1999 and 2001). Reproductive rates estimated for humpback whales off California have been lower than those reported for other humpback whale populations although this has not been consistent with the previous rate of increase for this population (Steiger and Calambokidis 2000).

Blue whale sightings and identifications

Blue whales were identified on 539 occasions during 2001 representing 274 unique individuals (Tables 7 and 15, Figure 3). This represents one of the highest annual totals for identifications since our blue whale research began in 1986 (only 1992 with 279 individuals was higher). More than half these identifications came from one relatively small area sampled in late July 2001. One of the largest concentrations of blue whales we have ever seen was encountered off the SW side of San Miguel Island from 24 to 26 July 2001. In an area estimated to be 8 nmi by about 1 nmi extending along the edge of the continental shelf break, we estimated a minimum of 200 blue whales. Because of the excellent weather (unusual in this area) and large number of

whales, we deployed two boats in this area on 25 and 26 July (one of the boats was engaged in Crittercam deployments on two days). This allowed us to obtain large number of identifications of blue whales in a short period. In the 3-day period we obtained 272 identifications of 132 individual whales (more than we have ever obtained in a single region in a year). Our number of identifications is an underestimate of the whales present since 45% of the individuals were seen only once (74% seen twice or less) despite the intense survey effort by two boats on three days all in a small area.

Although our sampling of this area occurred in a short time period, the whales appeared to be there over a much more extended period. Biologists based on San Miguel Island had been seeing whales in this region prior to our surveys. We also encountered a fairly large number of blue whales again in this area in late August during the *Sproul* surveys, but weather was not good and did not allow us to obtain identifications or to estimate numbers.

Blue whales were also encountered and identified in several other areas around southern California including off San Nicolas Island in June and July, around Tanner/Cortez Bank in both June and August, in the Santa Barbara Channel in June and off Pt. Arquello in both June and July. Blue whale sightings were less common in central and northern California. Identifications were obtained in the Gulf of the Farallones in August, between Half-Moon Bay and Monterey Bay in September and October, and in Monterey Bay in October (not including the opportunistic identifications by Nancy Black and Peggy Stapp from April to November).

Identifications from ORCAWALE cruises

While deployment and identification efforts for blue whales were very successful during the SWFSC systematic surveys, there were fewer than expected blue whale sightings and opportunities to obtain identification photographs. The small boat was deployed to obtain photographs of blue whales on 10 days. A total of 16 blue whales were approached with the small boat and identification photographs obtained of 13 of them. While 13 identifications is less than had been expected, the proportion of sightings that were successfully approached and identified was high (Table 3).

Abundance estimates

Humpback whales

The abundance of humpback whales from mark-recapture estimates using identifications from 2000 and 2001 was lower than some of the estimates from previous years (Table 16, Figure 4). The inter-year Petersen mark-recapture estimate based on all identifications from 2000 and 2001 yielded an estimate of 779 (CV=0.16). This estimate is similar to the one from last year, which represent a substantial decrease from previous estimates. From 1991 through 1999, humpback whale abundance estimates had increased steadily from 569 to 1,027 (Figure 4). The estimates from the last two years represent the first substantial decline in numbers. We explored several alternate samples to estimate abundance in order to try and identify any sources of bias or error in the abundance estimates.

One concern was that identifications obtained from southern California and northern waters including California, Oregon, and southern Washington was not as large in 2000 and 2001 as it had been in some previous years. To see if this could be biasing the mark-recapture estimates, we computed abundances using only identifications made in central California (Pt Sur to Pt. Arena). While this would likely bias the absolute estimates downward, it should eliminate inter-year differences caused by differences in number of identifications obtained in southern and northern waters. As expected the estimates generated tended to be lower than when using all regions, however, the pattern remained unchanged with increasing abundances through 1999 followed by lower estimates for the last two pair of samples. This suggests that the drop in recent estimates was not caused by biases due to geographic coverage.

We also tested whether changes in how we handled poorer quality photographs could have altered estimates. If we had become less tolerant of marginal-quality photographs in recent years, perhaps this would have biased our results towards a higher proportion of matches and therefore lower estimates. Restricting our estimates to only those photographs judged to be of highest quality, yielded more variable abundances estimates (to be expected with lower samples) but again did not alter the dramatic decline in estimates in the last two years. The lower recent estimates in humpback whale abundance therefore do not appear to be the results of biases caused by any inadvertent changes in our quality criteria.

We also estimated humpback whale abundance using identification samples obtained from different platforms (Table 16). In 2001, 23 humpback whales were identified during the SWFSC cruises that systematically covered the waters off California, Oregon, and Washington. Estimates based on comparison of this sample to all other identifications in 2001 (256) did yield a much higher estimate of abundance (1,541). Examination of the locations where samples were obtained shows why there were so few matches between these samples and hence the higher estimate of abundance (Figure 2). A majority of the humpback whale identifications obtained during the 2001 SWFSC cruises were off southern Washington, Oregon, and offshore California with only a few identifications in coastal waters of southern and central California, where most of the identifications were made from other vessels. This difference in locations would have made it less likely for the same whale to be photographed by both vessel types and would therefore have biased the estimates upward. It is not clear why the SWFSC identifications were obtained in such a different set of locations than our small boat operations. This could be the result of random chance since the systematic survey lines very sparsely cover the coastal habitat preferred by humpback whales and could easily have missed the few highly clumped areas of humpback whale concentration.

Examining abundance estimates using samples separated by 2-years does not appear to clarify the pattern (Table 16). Samples taken at 2-year intervals would be expected to over-estimate abundance due to violations of closure due to mortality and natality and the greater time-span would blur changes in abundance occurring over time. As expected these estimates were higher than the less biased (due to closure) estimates using adjacent-year samples. While these estimates are consistent with those obtained from our other sample pairs, the two-year

spread of these samples makes it harder to use them to verify the recent possible decline in humpback whales.

Jolly-Seber multi-year mark-recapture abundance estimates for humpback whales showed a similar pattern as the inter-year Petersen estimates (Table 17). These estimates show the abundance peaking in 1998 and declining for 1999 and 2000 (no estimate for 2001). There is a sharp decrease in the survival rate for animals starting in 1998, going from 0.87 to 0.97 for 1991 to 1997 and then dropping to 0.77 for 1998 to 1999 and 1999 to 2000 (the last two years estimates can be made).

Because we cannot identify a source of bias responsible for the drop in humpback whale abundance estimates, we are more confident concluding that this decrease is real. Our estimates point to a sharp decrease in abundance some time between 1998 and 1999. This is consistent with both the Jolly-Seber and Petersen estimates. The Petersen estimates would not show the decrease until both annual samples were collected after the decline (the estimate based on 1999 and 2000 samples). Given the generally low reproductive rate of this population and the absence on an observed decline in reproductive rate in recent years (Table 14), the magnitude of the decrease indicates it would have to primarily be caused by mortality or emigration of animals outside the area. There were not elevated numbers of strandings of humpback whales off California during the late 1990s (Table 18).

It is unclear if the decrease we saw may be the result of a short term phenomena or a longer-term trend. One possible short-term phenomenon responsible for a decreased survival in humpback whales would be the effects of the 1997-98 El Nino. This El Nino was considered severe and resulted in lower upwelling and productivity off California from spring 1997 through the fall of 1998. Zooplankton declines appeared to be more severe in many areas in 1998. Lower prey availability for humpback whales during the 1998 feeding seasons could produce a lower survival of animals over the following winter fasting period. It is unclear why survival rate remained low for the year following the El Nino.

There has also been evidence of declines in plankton off California that has apparently already affected some of the other apex-predators off California. Long-term declines in plankton off southern California have been documented from the 1970s to the mid-1990s (Roemmich and McGowan 1995). Dramatic declines have been noted in some krill-feeding marine seabirds off California, possibly in relation to this climate-driven change (Veit *et al.* 1997).

While humpback whales have been recovering from commercial whaling, it does not appear they have yet reached pre-whaling numbers. Humpback whales were hunted commercially off California through 1966 (Rice 1974). Based on the numbers of whales killed off California, Oregon, and Washington in fairly short periods (Clapham *et al.* 1997), the pre-whaling population appears to have numbered over 2,000 in this region. The current population of humpback whales is therefore below historical levels but declines in plankton discussed above could have diminished the carrying-capacity of humpback whales off California.

Blue whales

The abundance of blue whales was estimated using the identifications obtained during the SWFSC systematic surveys conducted off California, Oregon, and Washington. Because a portion of the blue whale population feeds in waters farther offshore than our coastal surveys are able to sample, they are not adequately represented in our small boat samples. We therefore use the identifications from the SWFSC systematic surveys as a representative sample that can be compared to our larger but not representative coastal sample.

Relatively few identifications were obtained during the 2001 SWFSC cruises as a result of the low sighting rate of blue whales during these cruises. Only 13 groups of blue whales, representing 16 whales were approached for photographic identification and good quality identification photographs obtained for 13 of them (12 with acceptable right side and 9 with acceptable left side photos).

The reason for the lower than expected sighting rates in the 2001 survey may in part be the clumped distribution of blue whales seen in late summer 2001. Although blue whales were encountered during the coastal photo-ID surveys in a number of areas, this year blue whales were more heavily concentrated in a relatively small area SW of San Miguel Island. The concentration of whales could easily have extended over a much larger area and included many more whales than we counted. This area of high blue whale concentration was not surveyed on any of the systematic SWFSC transect lines.

Although sample sizes were small from the SWFSC cruises, we did estimate abundance using these identifications and those obtained from the more opportunistic surveys in 2000 and 2001 (Table 19). Estimates using both left and right sides were lower than previously documented and averaged about 1,000. The low sample size resulted in very high uncertainty in these estimates and they cannot be used as yet to document a decline in abundance. Inclusion of additional effort in 2002, especially to increase the systematic component of the sample, will provide a more reliable estimate of abundance.

Annual samples from all areas were also used to estimate inter-year abundance of blue whales (Table 19). While these estimates likely underestimate true abundance due to the lack of representative coverage of blue whales feeding in more offshore waters, they do provide an index of abundance. Estimates using 2000 and 2001 samples were similar to those from previous years.

Tagging

Crittercam tag deployments were conducted during two periods and regions in 2001; one in the Sea of Cortez (Table 20) and the other in the Southern California Bight (Table 21). Field effort was conducted in the Sea of Cortez in collaboration with Diane Gendron of CICIMAR primarily from 26 February to 6 March 2001 with 16 deployments attempted between 28 February and 3 March. One extended deployment and recovery was achieved on a single feeding blue whale on 1 March. We achieved another extended deployment on 3 March but, despite an extensive search extending after our field effort, it was never recovered.

Data from the primary deployment covered more than 6 hours extending from daylight into night and showing the dramatic shift in depths of dives. Comparison of the dive profile of this animal with the presence of a krill layer (detected from a boat following behind the whale) showed it was diving to below the krill layer and then coming into the lower portion of the layer (Figure 5). This was also apparent in the video where a progression was seen of the animal diving down to where there was little light, then turning to come up towards the surface and then appearing to invert as it lunged and the speed slowed to a stop. This process is repeated for each of the lunges visible in the dive profile prior to the animal surfacing. That observation and the collection of feces confirmed they were feeding in this area. Identification photographs were obtained of most of the animals in this area and skin samples collected from many of them.

Our second deployment effort in 2001 was conducted in the southern California Bight from 14 to 26 July 2001 (Table 21). We had planned to work with the concentration of blue whales that typically feeds in the Santa Barbara Channel during this period. Unfortunately, there were very few blue whales present this year. We found two other areas with large blue whale concentrations just north of San Nicholas Island and southwest of San Miguel Island. Although both these areas were close to 50 nmi away from the nearest harbor, we were still able to effectively work in these areas with our two RHIBs. We had excellent success deploying Crittercams achieving 12 deployments, 5 of these for periods of greater than 15 minutes where the camera was recovered. We lost one camera, we suspect due to failure of the VHF transmitter, although this tag may still be recovered if it washes up on shore.

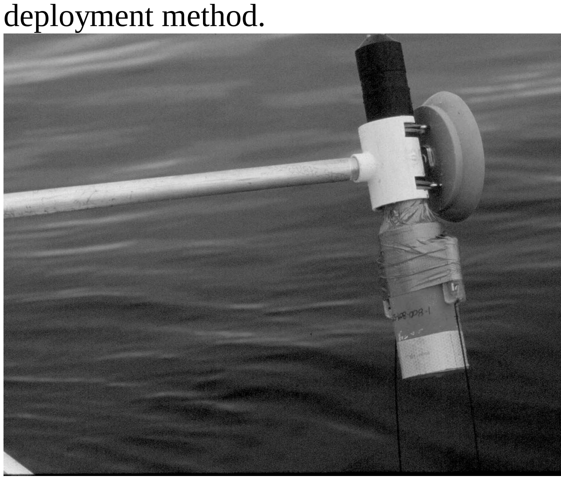
Records from the deployments off San Nicolas and San Miguel revealed that the animals were feeding much deeper than expected with most of the dives being down to 250-300m (Figure 6). That matched the water depth in these areas, which was just of the edge of the shelf and indicated the whales were diving to near the bottom. Video from the Crittercams revealed a constant stream of krill at what appeared to be a high density passing by the camera through most of the dive (other than near the surface). This observation and the deep dives may explain why we had trouble detecting a defined krill layer on our depth sounder. We would have had trouble detecting deep layers (our depth sounder has difficulty detecting the bottom or layers below 200m) and the krill layer was in an extremely broad band (based on the steady stream of krill on the camera) making detection of a defined layer more difficult. At the lower depth, it was not possible to see any light from the surface. Illumination (Leeds) provided by the Crittercam allowed detection of the krill and sound provided a clear cue of when the animal lunged and dramatically slowed in speed. On one deployment the Crittercam was attached more on the side of the animal just above the pectoral fin, and the throat pleads could clearly be seen distending during the lunges and immediately prior to the sound level indicating the animal had come to a stop.

Overall, our success in the proportion of approaches resulting in contact with the animal and the proportion of contacts resulting in successful attachment have increased with each deployment session (Table 22). Our higher success rate stems from several factors:

1. Refinement of our approach technique both in terms of being more effective in how we conduct it but also knowing when an approach would be unlikely to succeed and waiting for another opportunity.
2. Our success in getting an attachment stems from having more time and a better speed match for placing the tag, a better sense of where and how to place the tag on the animal, and improvements to the design including addition of a stabilizing arm that helps get the orientation correct to achieve a good seal with the suction cup.

In total there have been 19 deployments of Crittercams on blue whales (Table 23). In 17 of these the camera was successfully and recovered and in two cases the camera was never found. Both cameras were lost in 2001, one in the Sea of Cortez (see above) and the other from our initial deployment of San Nicolas Island. Some of the successful deployments were very short and only provided a small amount of data while in 8 cases the camera was on the whale for more than 15 minutes before coming off and being recovered.

Deployment of the acoustic tag developed by Bill Burgess of Greeneridge Scientific Services was part of an effort to both test the tag and gather some preliminary data on the vocal behavior of blue whales. Efforts in 2001 were primarily aimed at testing the tag and different delivery and attachment methods. Because the tag was still in development and not yet available encapsulated in resin, we worked with SIO and Joe Olson of Cetacean Research Technology to develop a pressure case for the instrument. Joe Olson also helped develop the delivery, attachment, and retrieval system for the tag. The tag was encased in a pressure case and had an attached flotation collar and two VHF transmitters. The tag was delivered with an aluminum pole with PVC bracket to hold the tag in place until attachment. Two attachment methods were tested one using four smaller suction cups mounted on a PVC bracket that used dissolving gummies to break the vacuum and the second involving a single larger cup with a magnesium corrosable link that would allow the tag to detach from the suction cup. See below for tag configuration and deployment method.



Tag with floatation and transmitters with single suction cup

Bill Burgess and Todd Chandler preparing to deploy acoustic tag (4-cup)

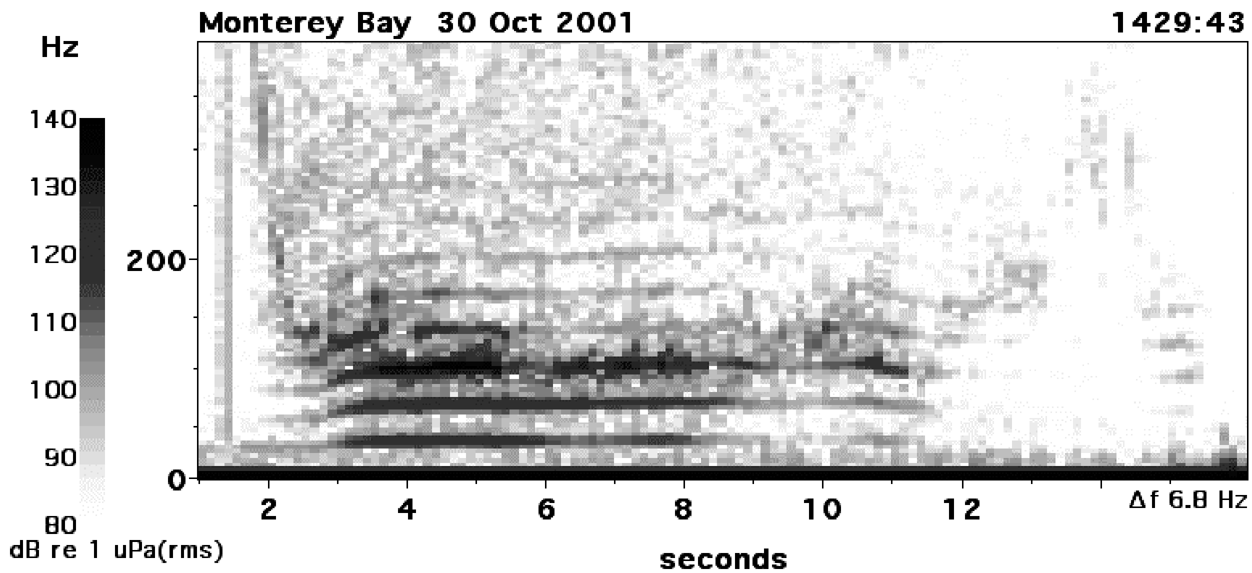

Deployment of acoustic tag on a blue whale in Monterey Bay.

The tag and pressure case performed well in tests where they were submerged in the presence of whales and recorded whale calls. Initial deployments were conducted on 26-28 August 2001 at Tanner/Cortez Bank during one of the SIO surveys with the *Sproul* using Cascadia's RHIB (Table 24). The following attempts were conducted:

- In the first deployment (using a single large suction cup) contact was made with too strong a force and the tag disconnected from the suction cup on contact, leaving the cup but not the tag attached to the whale.
- In the 2nd deployment (with 4 smaller suction-cups) we placed the tag on a blue whale and watched it submerge with the tag on. The tag came off within 5 minutes, however. The holes were still plugged but one of the cups was turned sideways. During attachment the tag slid up the back of the whale when force was applied and we think that one of the cups gripped and then twisted out of position.
- The third deployment was with the single cup again and this time the whole assembly slid up and over the back of the whale when pressure was applied thereby preventing attachment.

A second set of deployments was conducted in Monterey Bay in late October 2001 (Table 24). A few modifications had been made to the tag including addition of a pressure sensor to record water depth. We made seven close approaches to blue whales to apply the tag on this trip and appeared to have attached the tag on six of these. All of these attachments, however, ended up being extremely brief with the tag recovered within minutes of deployment, typically no more than 100 m from the deployment location. The tags did stay on even though in most cases we could see the whale going down with the tag on. Three of the deployments were with the larger single suction cup and three with the 4-cup design. All other aspects of the deployment seemed to go well and we thought we had good attachments. The cups on the tag held suction both before deployment and we verified they were still doing this after recovery (there was no failure in the gummies). On contact with the whale we did notice that when we applied pressure to the tag it was hard to avoid having it slide along the whales back. We experimented with a denture sealant to reduce this slippage but this made no difference. Our conclusion was that the tag inside the pressure casing with the added floatation was too large for the suction cups to hold in place for very long.

Electronics in the tag appeared to all be working, with the exception of the pressure sensor (installed prior to the second set of deployments) possibly due to an insufficient power-up delay in the sampling code. Data from the tag tests were successfully offloaded and looked good. During one of the short deployments at 1430 on 30 October 2001, a blue whale B call was recorded by the tag (see below). The strongest harmonic reached levels of just under 140 dB re 1 uPa, consistent with a 180-dB source at a range of 100 m.



Blue whale call recorded by acoustic tag briefly deployed on 30 October 2001 in Monterey Bay.

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Development of the acoustic tag was by Bill Burgess of Greeneridge Scientific Services. Joe Olson developed the pressure casing and the attachment method for the acoustic tag. Crittercam was developed by Greg Marshall of National Geographic. John Francis and Mehdi Baktiari were crucial to the successful deployments off California.

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TABLES AND FIGURES

Tables

Figures

Table 1. Summary of field effort by Cascadia Research personnel off California, Oregon and Washington in 2001.

Date	Ves-sel	Pers	Launch	Region	Loc. code	State	Time Start	Time End	Dura-tion	Dist nmi	Oth. activit.	Prim. Proj.	Skin	Dist nmi	Humpback whale Sight	Humpback whale Num	Humpback whale ID	Blue whale Sight	Blue whale Num	Blue whale ID
17-Apr	N2	KR	Moss Landing	MB	51	CA	6:45	13:19	6.6	42.8		ID			14	26	23			
19-Apr	N1	JAC	Westport	OC	75	WA	8:45	15:45	7.0	76.0	EJ scat col.	ER								
20-Apr	N2	KR	Moss Landing	MB	51	CA	6:53	7:32	0.7	1.6	Aborted	ID								
21-Apr	N2	KR	Moss Landing	MB	51	CA	10:32	11:13	0.7	8.4	Abort: swell	ID								
25-Apr	N1	JAC	Everett	NPS	79	WA	9:00	21:40	12.7	109.3	Whidbey, OO	ER								
12-May	N2	KR	Moss Landing	MB	51	CA	9:34	20:29	10.9	79.6		ID			18	30	22			
13-May	N2	KR	Moss Landing	MB	51	CA	7:42	12:45	5.1	37.5		ID			17	30	19			
21-May	N1	JAC	Westport	OC	75	WA	10:47	17:10	6.4	73.0	EJ scat col.	ER								
8-Jun	Land	AN	Gov Pt.	OR	72	OR														
13-Jun	N1	JAC	Westport	OC	75	WA	15:08	22:11	7.1	75.9	EJ scat col.	ER								
19-Jun	N2	JAC	Sproul	SC	31	CA	12:52	18:00	5.1	36.7		SIO	1					1	1	1
20-Jun	N2	JAC	Sproul	SBC	33	CA	8:06	21:00	12.9	83.0		SIO	4					5	5	3
21-Jun	N2	JAC	Sproul	Pt Arquello	41	CA	7:30	20:00	12.5	63.8		SIO	5					8	17	15
22-Jun	N2	JAC	Sproul	SBC	33	CA	7:00	20:50	13.8	60.7		SIO	9		1	1	1	10	24	12
23-Jun	SP		At sea	SC	31	CA												1	1	1
24-Jun	N2	JAC	Sproul	Pt Buchon	41	CA	6:40	13:39	7.0	20.9		SIO			12	34	20	2	2	1
25-Jun	N2	JAC	Sproul	San Nic	32	CA	7:35	18:15	10.7	43.2		SIO	6		1	2	0	36	58	18
26-Jun	N2	JAC	Sproul	Tanner/Cortez	31	CA	8:09	18:43	10.6	35.5		SIO	4					21	36	5
6-Jul	N1	JAC	Westport	OC	75	WA	10:30	19:10	8.7	98.3	EJ scat col.	ER								
12-Jul	N1	JAC	Crescent City	NCA	63	CA	13:50	18:50	5.0	61.0		ID								
14-Jul	N2	JAC	Santa Barbara	SBC	33	CA	7:00	15:40	8.7	70.3		CC			1	2	0			
15-Jul	N2	JAC	Channel Is. Hbr.	San Nic	32	CA	7:00	22:28	15.5	109.7	Deploy/lose CC	CC						14	21	10
16-Jul	N2	JAC	Channel Is. Hbr.	SC	32	CA	10:45	14:30	3.8	39.5	No sight	CC								
17-Jul	N1	TEC	San Luis	SC	41	CA	7:25	14:15	6.8	89.4		ID						6	8	2
18-Jul	N1	TEC	San Luis	SC	41	CA	8:28	16:35	8.1	109.1		ID								
18-Jul	N2	JAC	San Luis	SC	41	CA	8:30	14:42	6.2	77.3		ID			1	2	1			
19-Jul	N1	TEC	Channel Is. Hbr.	San Nic	32	CA	8:00	16:40	8.7	133.2		ID						9	9	4
19-Jul	N2	JAC	Channel Is. Hbr.	San Nic	32	CA	8:00	16:40	8.7	98.4	Attach CC	CC	1					5	6	0
20-Jul	N1	TEC	Channel Is. Hbr.	San Nic	32	CA	7:43	16:51	9.1	101.9		CC						14	16	1
20-Jul	N2	JAC	Channel Is. Hbr.	San Nic	32	CA	7:40	16:56	9.3	104.5	Attach 2 CC	CC	1					8	12	3
21-Jul	N1	TEC	Channel Is. Hbr.	San Nic	32	CA	7:52	19:12	11.3	113.0		CC						15	18	9
21-Jul	N2	JAC	Channel Is. Hbr.	San Nic	32	CA	7:45	19:15	11.5	106.1	Attach CC	CC	1					13	19	6
22-Jul	N2	JAC	Santa Barbara	SBC	33	CA	13:20	19:00	5.7	63.2		ID						1	2	1
23-Jul	N2	JAC	Santa Barbara	SBC	33	CA	11:00	16:45	5.8	62.0		ID						2	3	3
24-Jul	N2	JAC	Santa Barbara	San Miguel	32	CA	7:45	19:05	11.3	125.4		ID						37	60	39
25-Jul	N1	TEC	Gaviota	San Miguel	32	CA	7:27	19:04	11.6	92.1		ID			2	5	2	84	119	88
25-Jul	N2	JAC	Santa Barbara	San Miguel	32	CA	6:45	21:30	14.8	120.4	Attach 4 CC	CC	4		3	8	8	39	79	40
26-Jul	N1	TEC	Gaviota	San Miguel	32	CA	7:25	18:22	11.0	87.8		ID			1	1	1	93	129	105
26-Jul	N2	JAC	Santa Barbara	San Miguel	32	CA	8:10	18:08	10.0	109.3	Attach 3 CC	CC	1					11	20	1
4-Aug	N2	TEC	Bodega Bay	Cordell-Bodega	53	CA	8:19	19:15	10.9	147.1	Foggy	ID			2	4	1	2	3	1
5-Aug	N2	TEC	Half Moon Bay	GF	53	CA	6:30	21:02	14.5	99.3		ID			55	107	73	20	31	19
9-Aug	N2	TEC	Half Moon Bay	GF	53	CA	7:38	19:51	12.2	97.5		ID			30	66	47	8	11	6
17-Aug	N1	JAC	Depoe Bay	OR	72	OR	9:45	18:35	8.8	80.7		ID/ER								
19-Aug	N2	TEC	San Luis	SC	52	CA	7:46	12:33	4.8	72.7	Foggy	ID								
21-Aug	N2	JAC	Sproul	off San Diego	31	CA	12:45	16:35	3.8	20.1		SIO	3					3	3	1
21-Aug	SP		At sea	SC	31	CA												1	1	1
23-Aug	N2	JAC	Sproul	S San Miguel	32	CA	12:28	15:40	3.2	15.7		SIO						10	15	9
23-Aug	SP		At sea	SC	32	CA				19.0								2	6	2
24-Aug	N2	JAC	Sproul	N San Nic	32	CA	8:18	18:10	9.9	41.2		SIO	4					3	3	1
25-Aug	N2	JAC	Sproul	Tanner/Cortez	31	CA	16:47	19:55	3.1	6.8	Acoust. tag	SIO	2					4	5	4
26-Aug	N2	JAC	Sproul	Tanner/Cortez	31	CA	14:40	17:13	2.6	6.7	Acoust. tag	SIO	1					1	1	1
27-Aug	N2	JAC	Sproul	Tanner/Cortez	31	CA	11:50	19:30	7.7	21.7	Acoust. tag	SIO	1					5	8	3
28-Aug	N2	JAC	Sproul	Tanner/Cortez	31	CA	8:30	19:28	11.0	45.1		SIO	3					11	14	7
29-Aug	N2	JAC	Sproul	Tanner/Cortez	31	CA	6:25	19:30	13.1	69.7		SIO	5					10	15	10
8-Sep	Rus	TEC	At sea	Morro Bay	42	CA	11:29			0.0		ID			1	2	2			
11-Sep	N2	TEC	Half Moon Bay	HMB-MB	52	CA	8:00	17:45	9.8	89.7		ID			43	101	67	8	11	9
13-Sep	N1	JAC	La Push	WA	76	WA	8:25	19:18	10.9	98.8		ID/ER	1	120	4	8	5			
23-Sep	N1	JAC	La Push	WA	76	WA					Foggy	ID/ER								
24-Sep	N1	JAC	La Push	WA	76	WA					High swell	ER								
5-Oct	N1	JAC	La Push	WA	76	WA	8:40	19:26	10.8	132.6		ID/ER	1	165	7	11	8			
26-Oct	N2	JAC	Moss Landing	N MB	52	CA	8:37	19:45	11.1	98.9		ID			20	92	64	3	5	1
27-Oct	N2	JAC	Moss Landing	N MB	52	CA	8:20	17:55	9.6	103.7		ID			21	54	41	7	14	11
28-Oct	N2	JAC	Moss Landing	MB	51	CA	9:08	17:39	8.5	48.7	3 acst. tag dplmt	SIO						8	12	4
29-Oct	N2	JAC	Moss Landing	MB	51	CA	7:51	18:05	10.2	68.1	1 acst. tag dplmt	SIO	3 OO		2	2	1	7	10	0
30-Oct	N2	JAC	Moss Landing	MB	51	CA	8:35	17:52	9.3	37.1	3 acst. tag dplmt	SIO						6	10	2
1-Nov	N2	TEC	Bodega Bay	Bodega	53	CA	7:49	15:10	7.4	106.1	Foggy	ID								
9-Nov	N2	TEC	San Luis	San Luis	41	CA	7:25	15:35	8.2	130.5		ID			1	4	2			
Total		Days	67					Hours	522.1											

Table 2. Daily effort to obtain identification photographs during SWFSC ORCAWALE surveys in 2001.

Date	Vessel	Time Start	Time End	Duration	Dist nmi	Humpback whale Sight	Humpback whale Num	Humpback whale ID	Blue whale Sight	Blue whale Num	Blue whale ID	Gray whale Sight	Gray whale Num	Gray whale ID
31-Jul	J2	17:40	20:00	2.3	6.9									
1-Aug	J1	17:03	19:27	2.4	5.5									
4-Aug	J1	16:38	20:34	3.9	34.8									
4-Aug	J2	14:07	15:45	1.6	11.4				1	1	1			
6-Aug	J1	13:14	16:00	2.8	23.2									
12-Aug	J2	11:42	15:29	3.8	24.0	1	3	1						
14-Aug	J2	12:20	20:21	8.0	42.6									
17-Aug	J2	8:12	11:33	3.4	26.7	1	2	2						
21-Aug	J2	8:12	11:59	3.8	13.6							5	7	6
3-Sep	J2	17:04	18:13	1.2	2.8									
4-Sep	J2	9:56	14:56	5.0	17.5	3	5	2						
5-Sep	DSJ	7:13	7:13	0.0		1	2	1						
5-Sep	J1	13:47	16:02	2.3	18.2	1	3	2						
6-Sep	J1	9:27	15:22	5.9	57.4	2	3	2						
13-Sep	J1	15:31	19:39	4.1	30.6									
14-Sep	J1	14:23	15:53	1.5	3.0									
18-Sep	J2	10:55	17:07	6.2	68.3	1	2	0						
20-Sep	J1	8:22	18:09	9.8	82.7	2	4	3						
21-Sep	J1	8:22	19:06	10.7	86.9	5	8	5	2	2	2	2	2	2
22-Sep	J1	17:48	19:05	1.3	10.5									
23-Sep	J1	17:20	18:47	1.5	9.1									
24-Sep	J2	18:05	19:13	1.1	6.6				1	1	1			
26-Sep	J1	15:05	17:00	1.9	15.3				1	2	2			
27-Sep	J1	18:45	19:43	1.0	1.9									
28-Sep	J1	12:14	13:08	0.9	2.6									
30-Sep	J1	18:46	19:22	0.6	3.0				1	2	2			
2-Oct	J1	15:43	18:51	3.1	19.4				1	1	1			
9-Oct	J1	12:05	18:30	6.4	43.1				2	3	1			
19-Oct	J1	9:15	10:57	1.7	3.9									
21-Oct	J1	9:30	11:26	1.9	5.2				2	2	1			
24-Oct	J1	11:12	18:40	7.5	53.8									
3-Nov	DSJ	12:32	12:32	0.0	0.0									
4-Nov	J1	12:01	13:32	1.5	5.5									
8-Nov	J2	8:58	13:33	4.6	33.3									
15-Nov	MAC	16:29	16:29	0.0	0.0									
18-Nov	AR2	8:08	10:50	2.7	25.3				1	2	1			
18-Nov	MAC	16:52	17:13	0.3	2.7									
20-Nov	AR2	13:03	15:02	2.0	6.4									
23-Nov	MAC	15:40	17:00	1.3	15.4	2	4	2						
25-Nov	MAC	12:00	12:00	0.0	0.0	1	3	0						
26-Nov	AR2	15:18	17:06	1.8	4.1				1	1	1			
27-Nov	AR2	12:45	17:15	4.5	38.5	3	6	2						
28-Nov	AR2	10:50	16:03	5.2	46.8	2	4	2						

Table 3. Summary of blue whales identified from ORCAWALE cruises in 2001.

Date	Time	Latitude	Longitude	Ves.	Snum	Sp	No.	# ID	Pho	Roll	Frames	ID numbers	Comments
04-Aug-01	14 26	36 33.21	126 49.92	J2	32a	BM	1	1	ABD	2	7-15	618	Biopsy #2
21-Sep-01	09 50	42 48.66	124 40.39	J1	2	BM	1	1	TEC	40	8-17	1684	Damaged dorsal
21-Sep-01	17 35	43 34.50	124 24.85	J1	9	BM	1	1	TEC	41	10-15	810	Biop. DSJ010921-12
24-Sep-01	18 13	41 58.91	128 14.57	J2	232	BM	1	1	TEC	41,42	32-35,1-9	1749	Biop. DSJ010924-1
26-Sep-01	15 12	39 23.63	124 05.71	J1	240	BM	2	2	TEC	43	1-14	1701, 1724	Biop. DSJ010926-1&2
30-Sep-01	18 46	34 27.20	122 00.01	J1	261	BM	2	2	TEC	43	22-END	442, 1726	Biop. DSJ010930-10 trail; -11&12 lead; vis. Vert. On trail BM
02-Oct-01	15 53	34 02.48	119 09.20	J1	272	BM	1	1	TEC	44	1-10	1750	Biop. DSJ011002-7
09-Oct-01	12 10	32 24.22	118 55.99	J1	291	BM	2	1	TEC	45	1-6	1718	No biop. Attempt
21-Oct-01	09 40	41 59.07	128 25.57	J1	313	BM	1	1	TEC	46	9-18	1687	Biop. Miss
21-Oct-01	11 26	41 55.73	128 25.54	J1	1	BM	1	0	TEC	46	19-26	PQ	Biop. Miss
18-Nov-01	08 46	33 50.33	125 59.21	AR-2	415	BM	2	1	ABD	8	10-22	1761	fr. 15-22 biop. MAC011118-01
26-Nov-01	15 31	37 04.31	125 53.72	AR-2	452	BM	1	1	ABD	9	4-9	810	
							16	13					

Table 4. Summary of field effort by Cascadia Research personnel from whale-watch boats in 2001. Does not include Black/Stapp.

							Time		Dist	Humpback whale			Gray whale		
Date	**Vessel**	**Pers**	**Launch**	**Region**	**Loc code**	**State**	**Start**	**End**	**nmi**	**Sit #**	**An #**	**Pho #**	**Sit #**	**An #**	**Pho #**
25-Mar	St Nic	RL	Everett	NPS	NPS	WA	10:00	14:30	23.6				2	4	2
31-Mar	St Nic	RL	Everett	NPS	NPS	WA	10:00	14:30	30.3				2	3	1
8-Apr	St Nic	RL	Everett	NPS	NPS	WA	10:00	14:30	29.8				2	3	3
14-Apr	St Nic	BP	Everett	NPS	NPS	WA	10:05	14:30	39.8				2	2	1
22-Apr	St Nic	RL	Everett	NPS	NPS	WA	10:00	14:45	32.3				1	1	1
9-May	El Matador	RL	Westport	GH/OC	75	WA	12:58	15:22	19.4				1	5	3
8-Jun	Discovery	AN	Newport	OR	72	OR	11:30	13:40	8.2	1	1	0	4	7	3
15-Jun	Discovery	AN	Newport	OR	72	OR	11:30	13:37	8.8				1	3	2
15-Jun	Sea Star	AN	Depoe Bay	OR	72	OR	9:00	10:23	7.5				3	4	0
22-Jul	Discovery	AN	Newport	OR	72	OR	14:02	16:02	7.7				1	1	0
22-Jul	Sea Star	AN	Depoe Bay	OR	72	OR	11:05	12:25					3	4	2
10-Aug	Discovery	AN	Newport	OR	72	OR	11:39	12:40	2.2				1	1	1
10-Aug	Sea Star	AN	Depoe Bay	OR	72	OR	9:00	9:55	0.6				3	4	2
17-Aug	Discovery	AN	Newport	OR	72	OR	11:40	12:51	5.3				5	5	4
17-Aug	Sea Star	AN	Depoe Bay	OR	72	OR	9:10	10:15	3.4				3	3	3
6-Oct	Orca	AN	Depoe Bay	OR	72	OR	9:30	10:20	10.4				1	2	0
6-Oct	Discovery	AN	Newport	OR	72	OR	14:11	16:05	13.8				2	2	0
19-Oct	Discovery	AN	Newport	OR	72	OR	9:13	11:03	8.3				1	1	1

Table 5. Summary of opportunistic effort aboard whale-watch vessels in Monterey Bay by Peggy Stapp/Nancy Black in 2001.

	Ves-	Time		Dura-	Dist	Humpback whale			Blue whale		
Date	sel	Start	End	tion	nmi	Sight	Num	ID	Sight	Num	ID
4/26/01	PSC	7:26	15:41	8.3	65.7	4	14	0			
4/27/01	SW2	10:00	16:42	6.7	40.8	6	12	3			
4/28/01	SW2	7:03	16:18	9.3	48.7	8	17	5			
5/5/01	SW2	9:01	13:20	4.3	22.5	5	14	7			
5/6/01	SW2	7:01	12:37	5.6	21.6	5	10	5			
5/12/01	SW2	9:02	14:27	5.4	24.2	5	15	3			
5/13/01	SW2	9:01	14:38	5.6	35.0	4	19	3			
8/25/01	SW2	9:28	15:09	5.7	33.6				4	10	3
8/26/01	SW2	8:56	17:07	8.2	43.9	1	1	1	3	16	8
8/27/01	SW2	7:45	15:29	7.7	49.9	6	10	1	7	14	3
8/28/01	SW2	7:36	15:41	8.1	44.7	4	12	3	3	6	0
8/29/01	SW2	8:03	13:51	5.8	37.7	2	5	0	1	1	0
8/30/01	SW2	7:41	17:21	9.7	44.7	11	42	23	10	20	2
8/31/01	SW2	7:50	14:29	6.7	40.4	3	6	0	1	1	1
9/17/01	SW2	8:31	15:25	6.9	28.9	1	2	1	7	13	5
9/18/01	PSC	10:01	15:58	6.0	30.1						
9/18/01	SW2	7:56	8:33	0.6	5.1						
9/19/01	PSC	7:42	15:36	7.9	40.1				1	2	0
9/20/01	PSC	7:43	14:55	7.2	44.1				5	10	7
9/21/01	PSC	7:43	15:24	7.7	47.1				6	12	3
9/24/01	SOM	9:15	13:13	4.0	41.1	1	2	2			
10/1/01	SOM	9:04	14:52	5.8	44.2	2	4	4			
10/2/01	PSC	9:12	15:38	6.4	31.6	3	6	3			
10/3/01	PSC	9:07	15:46	6.7	47.5				1	1	0
10/5/01	SOM	9:12	14:33	5.4	33.5				1	1	0
10/7/01	SOM	9:14	14:57	5.7	37.8				1	3	4
10/8/01	SOM	9:11	14:03	4.9	25.3				2	3	2
10/9/01	SOM	9:17	14:26	5.2	31.4				2	3	2
10/10/01	SOM	9:03	14:49	5.8	33.7				5	7	5
10/11/01	SOM	9:00	14:53	5.9	28.4	1	1	1	2	9	2
10/12/01	SOM	9:08	14:26	5.3	41.8				5	9	4
10/13/01	SOM	9:12	14:07	4.9	37.3	1	2	1	2	4	2
10/14/01	PSC	9:07	14:38	5.5	27.6	2	4	4	3	4	1
10/17/01	PSC	9:02	14:58	5.9	27.4				5	8	4
10/18/01	SOM	9:04	14:45	5.7	39.1	2	3	0	6	10	4
10/20/01	SOM	9:12	15:01	5.8	39.0				2	2	1
10/21/01	SOM	9:16	14:41	5.4	40.9				2	2	2
10/31/01	PSC	9:04	13:20	4.3	24.3				1	1	1

Table 6. Summary of surveys conducted in 2001 using Cascadia boats.

		Month								
Region	**Code**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Total**
S Southern California Bight	31			2		6				8
N Southern California Bight	32			1	13	2				16
Santa Barbara Channel	33			2	3					5
Pt Conception to Buchon	41			2	3				1	6
Morro Bay	42						1			1
Monterey Bay	51	3	2					3		8
Half-Moon Bay	52					1	1	2		4
Gulf of the Farallones	53					3			1	4
N California	63				1					1
Oregon	72					1				1
Central Washigton	75	1	1	1	1					4
N Washington/BC	76						3	1		4
Puget Sound	79	1								1
Grand Total		5	3	8	21	13	5	6	2	63

Table 7. Number of blue whales identified in 2001 incl.SWFSC cruises and opportunistic surveys.

		Month						
Region	**Code**	**6**	**7**	**8**	**9**	**10**	**11**	**Total**
S Southern California Bight	31	6		30		1		37
N Southern California Bight	32	18	305	9		1	1	334
Santa Barbara Channel	33	15	5					20
Pt Conception to Buchon	41	2	2		2			6
Morro Bay	42	15						15
Monterey Bay	51			18	15	40		73
Half-Moon Bay	52			4	9	12	1	26
Gulf of the Farallones	53			22				22
Pt. Arena to Mendoci+A10n	61				2			2
N California	63				1	1		2
Oregon	72				2			2
Grand Total		56	312	83	31	55	2	539

Table 8. Number of humpback whales identified in 2001 including SWFSC cruises and opportunistic surveys.

		Month								
Region	**Code**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Total**
S Southern California Bight	31									
N Southern California Bight	32				9					9
Santa Barbara Channel	33			1	2					3
Pt Conception to Buchon	41			20	1				4	25
Morro Bay	42						2		2	4
Monterey Bay	51	31	59			28	3	14	2	137
Half-Moon Bay	52					20	67	105		192
Gulf of the Farallones	53					101				101
N California	63						3			3
Oregon	71-3					3	5			8
Central Washigton	75						7			7
N Washington/BC	76			2	8	1	13	28		52
Grand Total		31	59	23	20	153	100	147	8	541

Table 9. Summary of skin samples collected by Cascadia Research in 2001. In some cases duplicate samples were collected from the skin found on the suction cups but these are counted only once.

	Blue whales				Fin	Humpback	Orca	Total
Region	**Biopsy**	**From tag**	**Sloughed**	**Total**	**Biopsy**	**Biopsy**	**Biopsy**	
Off San Diego	3			3				3
Tanner/Cortez	15	2		17	1			18
N San Nicholas	10	3		13	1			14
Santa Barbara Channel	6		6	12				12
W San Miguel*	1	5	1	6				6
Pt Arguello	5			5				5
Monterey Bay							3	3
WA/BC border						2		2
All regions	40	10	7	56	2	2	3	63

* Sloughed skin and biopsy taken from one blue whale off W San Miguel, only counted once in species and other totals

Table 10. Number of fluke measuirements obtained for each species broken down by region and meeting specific criteria.

Sample	Whale species			All
	blue	gray	hump.	
By region				
CA-WA summer 1999			60	60
CA-WA summer 2000	1	5	48	54
CA-WA summer 2001	19	5	141	165
Costa Rica Jan-Feb 2000			9	9
Costa Rica Jan-Feb 2001			14	14
All areas	20	10	272	302
By criteria				
Photograph w/ distance	20	10	272	302
Measurable photo	19	9	235	263
Angle 15 degrees or less	11	8	197	216
Tips visible, not damaged	6	6	173	185
% usable	30%	60%	64%	61%

Table 11. Results of multiple fluke measurements of the same whale.

Species	Differ. whales	Measure- ments	<5% off mean	%
Humpback whale	30	83	66	80%
Blue whale	1	4	4	100%
Gray whale	1	2	2	100%
All	32	89	72	81%

Table 12. Proportion of duplicate high or low fluke measurement taken at unusualy low or high distances or at marginal angles.

Type	n	Dist <40m	Dist >80m	Angle >=10 deg
Low measurements	8	25%	25%	75%
High measurements	9	0%	33%	22%
High or low measurements	17	12%	29%	47%
Measurements <5% off mean	66	5%	20%	24%
All humpback measurements meeting criteria	182	6%	16%	26%

Table 13. Number of unique humpback whales identified by Cascadia and collaborators by year and region for California, Oregon and Washington through 2001.

		Number of individuals identified																
REGION	**Code**	**>86**	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**All**
S Ca. Bight (south)	31	0	0	0	0	0	0	1	0	5	3	0	0	4	0	0	0	0	12
S. Ca. Bight (north outside SBC)	32	0	0	0	1	0	1	0	3	1	6	18	0	0	5	0	0	4	37
Santa Barbara Channel	33	0	0	0	4	0	6	15	97	9	13	136	22	27	101	18	1	3	254
S. Califonria (offshore)	39	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	4
Pt Concpetion to Buchon	41	0	0	8	58	0	0	78	4	1	14	20	0	23	3	2	69	13	210
Pt Buchon to Pt. Sur	42	0	0	0	2	0	2	12	0	0	0	0	8	13	16	9	5	4	69
S Monterey Bay Sanc.	51	3	0	4	15	2	13	13	65	45	59	33	89	91	146	175	144	71	553
N Monterey Bay Sanc.	52	0	0	0	2	0	20	0	0	26	4	42	82	47	30	12	0	115	315
Farallones/Cordell	53	16	90	140	133	110	161	89	172	181	164	127	168	34	89	116	33	83	748
Bodega Bay to Pt. Arena	54	0	1	0	5	0	0	0	63	6	0	0	4	5	22	2	0	0	104
C. California offshore	59	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	4
Pt. Arena to C. Mendocino	61	0	0	0	0	0	0	4	73	2	0	0	0	23	22	0	0	0	119
C Mend. to Klamath Riv.	62	1	0	0	8	0	0	4	0	4	0	12	8	26	6	0	0	0	61
N California to Oregon	63	0	0	0	3	0	0	85	50	16	0	1	0	14	69	6	0	3	188
S Oregon	71	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	5	7
C. Oregon	72	0	0	0	0	0	22	0	0	0	0	0	7	0	0	30	9	2	66
N Oregon	73	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	1	7
Washington	75	0	0	0	0	0	5	0	0	0	0	0	0	0	1	0	0	6	12
Wash/BC border	76	0	0	0	1	1	10	13	0	3	16	35	34	22	29	21	22	35	137
Puget Sound	79	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
All		20	91	150	213	111	218	282	398	257	260	365	366	288	418	349	252	311	1323

Table 14. Reproductive rates of humpback whales off California based on photo-identification. Total m/c (mothers or calves) identified uses whichever was higher (including tentative identifications). The total number of whales identified includes mothers and calves. See Calambokidis et al. (2000) for analysis of 1986-96.

	# of mothers IDed		# of calves IDed		Total identified		
Year	**definite**	**tentative**	**definite**	**tentative**	**m/c**	**all**	**Rate**
86	1	0	1	0	1	88	1.1%
87	3	1	3	1	4	143	2.8%
88	7	1	3	1	8	170	4.7%
89	1	0	3	0	3	62	4.8%
90	3	1	2	0	4	126	3.2%
91	8	3	5	3	11	225	4.9%
92	8	3	2	2	11	350	3.1%
93	10	1	9	2	11	214	5.1%
94	5	0	5	0	5	205	2.4%
95	17	8	15	4	25	314	8.0%
96	10	6	7	3	16	306	5.2%
97	15	1	4	2	16	265	6.0%
98	18	2	6	2	20	389	5.1%
99	13	5	7	2	18	348	5.2%
00	10	0	5	0	10	230	4.3%
01	11	6	6	4	17	276	6.2%

*number of calves used instead of mothers in 1989 because it is higher

Table 15. Number of unique blue whales identified by Cascadia and collaborators by year and region for California through 2001.

		Number of individuals identified																	
REGION	**Code**	**>86**	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**All**
S Ca. Bight (south)	31	1	0	0	0	0	5	17	0	7	1	33	16	11	43	0	9	19	156
S. Ca. Bight (north outside SBC)	32	2	2	0	0	0	0	1	19	5	34	90	9	22	0	0	0	162	309
Santa Barbara Channel	33	0	0	0	0	0	0	0	106	0	144	102	77	102	77	121	16	9	540
S. California (offshore)	39	3	1	0	0	0	0	20	0	32	0	0	8	0	0	0	0	0	64
Pt Concpetion to Buchon	41	0	0	0	0	0	0	4	0	2	6	5	2	8	0	0	18	6	51
Pt Buchon to Pt. Sur	42	0	0	0	0	0	0	0	0	2	0	0	7	0	0	6	3	9	27
S Monterey Bay Sanc.	51	9	42	62	25	15	0	0	6	18	18	8	21	10	84	16	95	41	381
N Monterey Bay Sanc.	52	0	0	0	0	0	2	0	1	45	0	3	4	4	1	5	0	19	82
Farallones/Cordell	53	9	36	74	95	64	102	27	109	25	29	7	26	40	22	42	46	20	426
Bodega Bay to Pt. Arena	54	0	0	0	17	1	0	0	20	0	1	0	4	5	0	3	0	0	47
C. California offshore	59	0	0	0	0	0	0	3	0	9	0	0	2	0	0	0	0	0	14
Pt. Arena to C. Mendocino	61	0	0	0	0	0	0	2	92	0	0	0	0	4	7	0	0	2	104
C Mend. to Klamath Riv.	62	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	4
N California to Oregon	63	0	0	0	0	0	0	4	4	0	0	0	0	0	7	0	0	2	17
Oregon	71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
All		24	79	129	122	77	109	76	279	126	208	229	168	181	226	177	170	274	1361

Table 16. Humpback whale abundance off California, Oregon, and Washington using Petersen mark-recapture estimates with annual samples. Coefficients of variation (CV1 and CV2) are based on analytical formulae and jackknife (respectively).

	Sample 1				Sample 2							
Period	**Year**	**Subs.**	**Ident.**	**n**	**Year**	**Subs.**	**Ident.**	**n**	**Match**	**Est.**	**CV1**	**CV2**
Annual samples using all data												
1991-92	1991	7	668	269	1992	8	1,023	398	188	**569**	0.03	0.051
1992-93	1992	8	1,023	398	1993	6	512	254	173	**584**	0.03	0.057
1993-94	1993	6	512	254	1994	6	402	244	108	**572**	0.05	0.148
1994-95	1994	6	402	244	1995	9	661	331	100	**804**	0.06	0.166
1995-96	1995	9	661	331	1996	7	564	331	144	**759**	0.05	0.078
1996-97	1996	7	564	331	1997	7	382	264	104	**837**	0.06	0.164
1997-98	1997	7	382	265	1998	8	854	389	117	**878**	0.06	0.132
1998-99	1998	8	854	389	1999	6	613	331	125	**1,027**	0.06	0.097
1999-2000	1999	6	613	331	2000	8	615	232	107	**715**	0.06	0.172
2000-01	2000	8	615	230	2001	7	489	276	81	**779**	0.07	0.16
Annual samples using only best quality identifications												
1997-98 Best	1997	7	104	88	1998	8	209	160	21	**650**	0.17	0.352
1998-99 Best	1998	8	209	160	1999	6	198	147	21	**1,082**	0.18	0.238
1999-2000 Bes	1999	6	195	147	2000	8	119	89	25	**511**	0.15	0.208
2000-01 Best	2000	8	119	89	2001	7	226	172	28	**536**	0.14	0.251
Annual samples at 2-year intervals												
1996-98	1996	7	565	332	1998	8	854	389	143	**901**	0.05	0.086
1997-99	1997	7	384	266	1999	6	613	331	80	**1,093**	0.08	0.104
1998-2000	1998	8	854	389	2000	8	615	232	105	**856**	0.06	0.12
1999-2001	1999	6	613	331	2001	7	489	276	93	**977**	0.07	
Comparison by vessel type												
2001 Ves	SWFSC		24	23			465	256	3	**1,541**	0.41	
Annual samples restricted to central California (Pt Sur to Pt Arena)												
1991-92	1991	7	414	176	1992	8	598	262	86	**534**	0.06	0.127
1992-93	1992	8	598	262	1993	6	464	225	112	**525**	0.05	0.079
1993-94	1993	6	464	225	1994	6	371	226	98	**517**	0.06	0.162
1994-95	1994	6	371	226	1995	9	360	201	60	**751**	0.09	0.17
1995-96	1995	9	360	201	1996	7	517	305	92	**664**	0.06	0.081
1996-97	1996	7	517	305	1997	7	272	195	83	**713**	0.07	0.153
1997-98	1997	7	272	195	1998	8	534	253	65	**753**	0.09	0.146
1998-99	1998	8	534	253	1999	6	533	283	85	**838**	0.07	0.109
1999-2000	1999	6	533	283	2000	8	605	220	100	**620**	0.06	0.154
2000-01	2000	8	605	220	2001	7	459	252	80	**689**	0.07	0.156

n-Number of unique individuals in sample used in mark-recapture estimate

Est.-Estimated abundance

CV1-Coeficient of variation based on Chapman

CV2-Alternate estimate of coefficient of variation using Jackknife proceedure (see Methods)

Table 17. Model parameters and population estimates from Jolly-Seber mark-recapture method using California, Oregon, and Washington (not incl. WA/BC border) for 1991-2001.

Year	**IDs**	**Prev IDs**	**r**	**z**	**Surv**	**Births**	**Marked available**	**Popul. estimate**	**SE**
1991	269	0	252	0	0.97				
1992	398	188	352	64	0.95	47	260	550	17
1993	254	199	223	217	0.96	84	446	569	17
1994	244	186	211	254	0.97	147	480	628	22
1995	331	228	267	237	0.97	64	522	756	27
1996	332	252	238	252	0.89	41	603	794	29
1997	266	216	187	274	0.93	116	605	745	30
1998	389	293	207	168	0.77	154	608	807	34
1999	331	231	154	144	0.77	-5	539	772	43
2000	230	192	81	106			491	587	45
2001	276	187	0	0					
Mean	302	197	197	156	1	81	506	690	
SD	58	73	94	101	0	55	110	104	

Table 18. Number of stranded humpback whales reported off California (from the National Marine Fisheries Service, Southwest Region, California Marine Mammal Stranding Network Database).

Year	# Srandings	Pooled Yrs	Mean
1983	2		
1984	2		
1985	0		
1986	0		
1987	0		
1988	0		
1989	0	1983-89	0.6
1990	1		
1991	1		
1992	3		
1993	8		
1994	1		
1995	5		
1996	1	1991-6	3.2
1997	4		
1998	2	1997-8	3.0
1999	0		
2000	4		
2001	2	1990-9	2.9

Table 19. Summary of Petersen mark-recapture estimates for blue whales off California and W. Baja Mexico.For each sample, the number of unique identified whales in each sample (n1 and n2) and the number of matches or recaptures (m) are indicated. Coefficients of variation (CV1 and CV2) are based on analytical formulae and jackknife (respectively).

Samples used	Left sides						Right sides						Mean
	n1	**n2**	**m**	**Est.**	**CV1**	**CV2**	**n1**	**n2**	**m**	**Est.**	**CV1**	**CV2**	
Pooled years using survey type as samples													
1991-93 all qualities	61	293	8	**2,024**	0.29	0.40	74	289	10	**1,976**	0.26	0.32	**2,000**
1995-97 all qualities	43	350	7	**1,930**	0.30	0.37	34	361	7	**1,583**	0.29	0.30	**1,756**
2000-2001 all qualities	9	297	3	**744**	0.34	0.58	12	288	2	**1,251**	0.44	1.51	**998**
Annual samples using all types (all quality)													
1991-1992	57	241	19	**701**	0.17	0.44	70	242	22	**749**	0.16	0.36	**725**
1992-1993	241	108	39	**658**	0.11	0.28	242	98	29	**801**	0.14	0.58	**730**
1993-1994	108	169	17	**1,028**	0.20	0.70	98	166	10	**1,502**	0.26	0.70	**1,265**
1994-1995	169	174	26	**1,101**	0.16	0.20	166	180	27	**1,079**	0.16	0.17	**1,090**
1995-1996	174	135	24	**951**	0.16	0.18	180	124	16	**1,330**	0.21	0.50	**1,140**
1996-1997	135	145	22	**862**	0.17	0.34	124	149	26	**693**	0.15	0.29	**778**
1997-1998	145	216	46	**673**	0.11	0.13	149	125	27	**674**	0.15	0.17	**674**
1998-1999	216	144	38	**806**	0.12	0.15	125	148	24	**750**	0.16	0.31	**778**
1999-2000	144	125	25	**702**	0.16	0.39	148	130	30	**629**	0.14	0.22	**665**
2000-2001	125	209	31	**826**	0.14	0.19	130	192	24	**1,010**	0.16	0.34	**918**

Table 20. Approaches to place Crittercam tags on blue whales off S California in July 2001.

Date	Region	Time	Latitude	Longitde	Num	SN#	Prim beh.	Activity	Reaction	Samples	Comment
28-Feb	Baja	14:09	25 04.61	110 49.33	1	N2-5	Milling	Close appr., no contact	Accelerate		
1-Mar	Baja	9:09	25 02.22	110 45.78	1	N2-3	Milling	Close appr., no contact	Accelerate	Skin A	
1-Mar	Baja	9:40	25 03.42	110 47.26	1	N2-4	Milling	Close appr., no contact	Accel., underwater blow, extend surf ser. dive		
1-Mar	Baja	9:54	25 03.31	110 47.57	1	N2-5	Milling	Contact, brief attachment	Accelerate	Skin B	Magn. disolved
1-Mar	Baja	10:20	25 03.72	110 47.33	1	N2-7	Milling	Contact, brief attachment	Accelerate and sink	Skin C	
1-Mar	Baja	11:04	25 03.62	110 47.81	1	N2-11	Milling	Appr., contact but no attac	None	Skin D	
1-Mar	Baja	11:29	25 03.80	110 47.94	1	N2-14	Milling	Close appr., no contact			
1-Mar	Baja	11:43	25 04.41	110 47.31	1	N2-15	Milling	Contact, brief attachment	Terminates surface series	Skin E	Skin blocks valve
1-Mar	Baja	14:30	25 02.87	110 46.09	1	N2-20	Milling	Appr., contact but no attac	Extends surf. ser. dive		On ridge
1-Mar	Baja	15:31	25 02.55	110 46.11	1	N2-23	Milling	Deploy on single	Slight exten. of surf ser. dive	Sm. skin from CC pos. other whale	
2-Mar	Baja	17:30	24 58.37	110 43.02	1	N2-8	Milling	Close appr., no contact	Sink, terminates surf. ser.		
2-Mar	Baja	18:06	24 58.37	110 43.02	1	N2-8	Milling	Close appr., no contact	Sink, extends surf. ser. dive. accel.		
3-Mar	Baja	8:00	24 59.82	110 43.94	1	N2-2a	Milling	Close appr., no contact	Sink, terminates surf. ser.		
3-Mar	Baja	8:33	24 59.82	110 43.94	1	N2-2b	Milling	Close appr., no contact	Extends surf. ser. dive		
3-Mar	Baja	8:55	24 59.82	110 43.94	1	N2-2b	Milling	Close appr., no contact	Extends surf. ser. dive		
3-Mar	Baja	9:14	25 02.36	110 44.94	1	CI-27B	Milling	Deploy on single, lost	Slight sink	Sloughed skin	

Table 21. Approaches to place Crittercam tags on blue whales off S California in July 2001.

Date	Region	Time	Latitude	Longitde	Num	SN#	Prim beh.	Activity	Reaction	Comments
15-Jul	N San Nic. Is.	11:36	33 26.06	119 36.03	1	N2-4	Mill	Appr., no contact	Accel., turns partly on side	
15-Jul	N San Nic. Is.	11:44	33 26.33	119 35.67	1	N2-4	Mill	Appr., no contact	Extend surf ser. dive, turns partly on side	
15-Jul	N San Nic. Is.	12:13	33 26.23	119 36.22	2?	N2-5	Mill	Appr., no contact	No Reaction	
15-Jul	N San Nic. Is.	12:39	33 26.16	119 36.01	1	N2-6	Mill	Appr. and attach CC	Sink Interupt surf. ser.	None/lost
19-Jul	N San Nic. Is.	12:40	33 23.13	119 32.11	1-2	N2-7	Mill	Appr. and attach CC	None	?
20-Jul	N San Nic. Is.	12:25	33 23.40	119 31.26	1	N2-5	Mill	Appr. and attach CC	Sink then accelerate	010720CC1A&B
20-Jul	N San Nic. Is.	12:58	33 23.19	119 31.07	1	N2-7	Mill	Appr. and attach CC		
21-Jul	N San Nic. Is.	13:20	33 23.16	119 29.36	1	N2-9	Mill	Appr., no contact	Sink, interupt surf. ser.	
21-Jul	N San Nic. Is.	13:34	33 23.15	119 29.37	1	N2-10	Mill	Appr. and attach CC	Sink response	
21-Jul	N San Nic. Is.	15:27	33 22.49	119 29.48	1	N2-15	Mill	Appr., contact but no attac	Quick sink and interupt surf. ser.	
25-Jul	W San Miquel	10:40	34 03.09	120 33.79	2(trail)	N2-12	Mill	Appr., no contact	Quick sink and turn	
25-Jul	W San Miquel	11:03	34 02.63	120 33.58	2 (trail)	N2-13	Mill	Appr., contact but no attac	Sink and terminates surf. ser.	Air not on in time
25-Jul	W San Miquel	11:27	34 03.95	120 35.14	1	N2-15	Mill	Appr., no contact	Aborts surf. ser.	
25-Jul	W San Miquel	12:05	34 05.13	120 35.19	2 (trail)	N2-17	Mill	Appr., contact but no attac	Extends surf. ser. dive	Does not lay flat
25-Jul	W San Miquel	12:12	34 05.29	120 35.79	2 (trail)	N2-18	Mill	Appr. and attach CC	Rolls on side and extends surf ser. dive	
25-Jul	W San Miquel	13:37	34 05.06	120 35.80	2 (trail)	N2-22	Mill	Appr. and attach CC	Extends surf. ser. dive, accelerates	
25-Jul	W San Miquel	15:04	34 04.97	120 35.70	2 (trail)	N2-25	Mill	Appr. and attach CC	Sink, accelerates	
25-Jul	W San Miquel	15:50	34 05.85	120 36.63	2 (trail)	N2-28	Mill	Appr. and attach CC	Sink, terminates surf.ser.	
26-Jul	W San Miquel	11:53	34 04.51	120 35.19	1	N2-6	Mill	Appr., contact but no attac	Accelerates, terminates surf.ser.	
26-Jul	W San Miquel	12:28	34 07.44	120 37.11	2 (lead)	N2-7	Mill	Appr. and briefly attach C	NR, trail: underwater blow, term. surf ser.	
26-Jul	W San Miquel	13:16	34 07.67	120 37.71	2 (trail)	N2-8	Mill	Appr. and briefly attach C	Accelerates	
26-Jul	W San Miquel	13:30	34 07.81	120 37.76	1	N2-9	Mill	Appr., contact but no attac	Accelerates, extends surf ser. dive	Medi falls down
26-Jul	W San Miquel	13:40	34 07.9	120 37.5	2 (trail)	N2-10	Mill	Appr., no contact	Accelerates, terminates surf.ser.	
26-Jul	W San Miquel	13:42	34 07.86	120 37.53	2 (trail)	N2-11	Mill	Appr. and briefly attach C	Accel. to high speed, side lunge next ss	
26-Jul	W San Miquel	14:18	34 07.98	120 37.56	1	N2-12	Mill	Appr., contact but no attac	Accelerates, terminates surf.ser.	
26-Jul	W San Miquel	14:30	34 07.93	120 37.28	1	N2-13	Mill	Appr., no contact	Accelerates	

Table 22. Success rate in approaching blue whales to attach Crittercams.

	Approaches	Contact		Attach		Recovered		>15 Min	
		#	%	#	%	#	%	#	%
Bodega 1999	10*	7	<70%	1	<10%	1	<10%	1	<10%
Monterey 2000	6	3	50%	1	17%	1	17%	1	17%
Baja 2001	16	7	44%	5	31%	4	25%	1	6%
S Cal 2001	26	18	69%	12	46%	11	42%	5	19%
Total	58	35	60%	19	33%	17	29%	8	14%

* Minimum

Table 23. Summary on deployments of Crittercam tags on blue whales 1999-2001.

		Deployment			Off	Recovery												
Date	**Region**	**Time**	**Latitude**	**Longitde**	**Time**	**Time**	**Latitude**	**Longitde**	**Num**	**SN#**	**Prim beh.**	**Type of deployment**	**Track data**	**Dive**	**IDs**	**Skin**	**Reaction**	**Comments**
20-Sep-99	Cordell Bank	14:13	38 04.77	123 22.02	15:40	15:40	37 56.47	123 27.30	2	7	Traveling	Deploy on lead of pair	Good positions	Yes	576 - CC 006 - trail	Skin from CC (#?)	Quick sink and accel.	
14-Sep-00	Monterey Bay	9:47	36 48.02	121 57.40	>20:00	17-Sep	36 31.57	122 17.80	2	4	Milling	Deploy on lead of pair	Good except for brief period	Lost	111 - CC 283 - trail	Biopsy lead-CC (BM00-11), trail (BM00-12)	Quick dive continues ss	Recovered 3 days later
1-Mar-01	Sea of Cortez	9:54	25 03.31	110 47.50	10:03	10:03	25 03.31	110 47.50	1	5	Milling	Brief deployment on single	Too brief	No	Video only	Skin from CC, Sample B	Accel	Premature magnesium
1-Mar-01	Sea of Cortez	10:20	25 03.72	110 47.33	10:23	10:23	25 03.76	110 47.38	1	7	Milling	Brief deployment on single	Too brief	No	Video only	Skin sample from CC, sample C	Accelerate and sink	Leak does not stick down
1-Mar-01	Sea of Cortez	11:43	25 04.41	110 47.31	11:47	11:50	25 04.55	110 47.53	1	15	Milling	Contact, brief attachment	Too brief	No	None	Skin sample from CC, sample E	Terminates surface series	Valve blocked by skin?
1-Mar-01	Sea of Cortez	15:31	25 02.55	110 46.11	22:05	23:14	25 02.07	110 46.67	1	23	Mill	Deploy on single	Excellent until dark	7 h BW3-1-01	JAC 5/6-9 poor	Sm. skin from CC pos. other whale	Slight exten. of surf ser. dive	
3-Mar-01	Sea of Cortez	9:14	25 02.36	110 44.94	>16:00	lost			1	CI-27B	Mill and travel	Deploy on single, lost after traking >6 h	Excellent	Lost	1627	Sloughed skin from footprints	Slight sink	
15-Jul-01	N San Nic. Is.	12:39	33 26.16	119 36.01	>13:00	lost			1		Mill	Deploy on single, lost signal after 13:27	NA	Lost		None	Sink, interupt ss	
19-Jul-01	N San Nic. Is.	12:40	34 23.13	119 32.11	~13:15	~13:15	34 23.27	119 32.24	1	7	Mill	Deploy on single, p/u time and pos NA, data lost on	Single update only	Lost on recycle		Skin from CC 010719CC1A&B	None	
20-Jul-01	N San Nic. Is.	12:25	33 23.40	119 31.26	12:27	12:32	33 23.42	119 31.48	1	N2-5	Mill	Deploy on single, comes off quickly	None in short period	Part of 1st dive		Skin from cup 010720CC1A&B	Sink then accelerate	
20-Jul-01	N San Nic. Is.	12:58	33 23.19	119 31.07	13:20	13:38	33 23.25	119 30.60	1	N2-7	Mill	Deploy on single	A few positions in 22 min	Almost all of 1st dive	Todd has best	None	None	
21-Jul-01	N San Nic. Is.	13:34	33 23.15	119 29.37	13:50	~14:15	33 23.0	119 28.77	1	N2-10	Mill	Deploy on single	No	1+ dives		Skin from cup 010721CC1A B is pos prev depl.	Sink	
25-Jul-01	W San Miquel	12:12	34 05.29	120 35.79	12:45	12:57	34 05.29	120 35.81	2 (trail)	N2-18	Mill	Deply on trail	Yes	2+ dives	JAC 34/34 35/1-3	Skin from cup 010725CC1A&B	Rolls on side and extends surf ser. dive	
25-Jul-01	W San Miquel	13:37	34 05.06	120 35.80	14:24	14:28	34 05.77	120 36.53	2 (trail)	N2-22	Mill	Deploy on trail	Yes	2+dives	BW and KR64	Skin from CC (CC3A&B) & sloughed (2A) and biopsy (2B) of	Extends surf. ser. dive, accelerates	Camera working?
25-Jul-01	W San Mique	15:04	34 04.97	120 35.70	15:10	15:17	34 05.13	120 35.77	2 (trail)	N2-25	Mill	Appr. and attach CC	No	Part of 1 dive only	None	Skin from cup 010725CC4	Sink, accelerates	
25-Jul-01	W San Mique	15:50	34 05.85	120 36.63	15:55	15:55	34 05.81	120 36.66	2 (trail)	N2-28	Mill	Appr. and attach CC	Off on 1st series	No	None	Skin from cup 010725CC5	Sink, terminates surf.ser.	
26-Jul-01	W San Mique	12:28	34 07.44	120 37.11	12:30	12:30	34 07.44	120 37.11	2 (lead)	N2-7	Mill	Appr. and briefly attach CC	No	No	No	No	NR, trail: underwater blow, term. surf ser.	
26-Jul-01	W San Mique	13:16	34 07.67	120 37.71	13:17	13:17	34 07.67	120 37.71	2 (trail)	N2-8	Mill	Appr. and briefly attach CC	No	No	No	No	Accelerates	
26-Jul-01	W San Mique	13:42	34 07.86	120 37.53	13:45	~13:47	34 07.9	120 37.5	2 (trail)	N2-11	Mill	Appr. and briefly attach CC	No	No	No	Skin from cup 010726CC1	Accel. to high speed, side lunge next ss	

Table 24. Summary on deployment attempts of acoustic tags on blue whales in 2001.

		Deployment			Off	Recovery										
Date	**Region**	**Time**	**Latitude**	**Longitde**	**Time**	**Time**	**Latitude**	**Longitde**	**Num**	**SN#**	**Prim beh.**	**Type of deployment**	**IDs**	**Skin**	**Reaction**	**Comments**
26-Aug-01	Tanner/Cortez	15:45	32 29.38	119 04.38	15:45	15:45			1	141	9	Single cup	JAC 45/18-19	010826-1	Terminates surface series, leaves area	Cup attaches but connection to tag breaks releasing tag
27-Aug-01	Tanner/Cortez	17:16	32 41.40	119 12.49	17:20	17:26	32 41.38	119 12.46	2	4	9	4-cup design		010827-1	Sink	Slides up back and one cup turns sideways
28-Aug-01	Tanner/Cortez	17:06	32 42.20	119 12.52	17:06	17:06			1	9	9	Single cup	JAC 46/12	None	Sink, terminates surf. ser.	Slides up back to ridge and fails to get good attachment
28-Oct-01	Monterey Bay	11:03	36 39.141	122 01.068	11:04	11:05	36 39.148	122 01.061	2 (trail)	2	9	Single gr. cup on trail	JAC 64/1-7	None	NR	Slides when applied but then appeared to hold
28-Oct-01	Monterey Bay	13:48	36 40.533	122 00.598	13:48	13:49	36 40.552	122 00.586	2 (trail)	5	9	Single gr. cup on trail	JAC 64/13-18	None	Sink	
28-Oct-01	Monterey Bay	14:01	36 40.473	122 00.813	14:02	14:02	36 40.468	122 00.843	2 (lead)	5		Single gr. cup on lead	JAC 64/13-18	None	Sink and turn	Slides when applied but visible on whale as it goes
29-Oct-01	Monterey Bay	15:42	36 42.138	121 59.000	15:43	15:43	36 42.152	121 58.989	1	10	9	4-cup design	JAC Col/29	None	Sink	Slides possibly out of position on contact, high
30-Oct-01	Monterey Bay	14:06	36 42.041	121 59.899	14:08	14:08	36 42.055	121 59.870	1	4a	9	4-cup design w/ Poly-Grip	?	Some w/ Polygrip 011030-1	Sink and interupt surf. ser.	Slides around on aplpication then holds, Polygrip does not seem to help
30-Oct-01	Monterey Bay	14:29	36 42.021	121 59.174	14:34	14:38	36 42.148	121 59.123	1	4b(sm df)	9	4-cup w/o Polygrip	JAC 64/24-25, 27-29, Col/30-32	16:58 biopsy 011030-2	Sink, surf. ser. interupt then resume	Attached underwater with quick jab, seen on whale underwater, B-call recorded
30-Oct-01	Monterey Bay	15:00	36 42.017	121 59.161					1	4b	9	Close apprch, no contact	Same as above			Same animal as previous

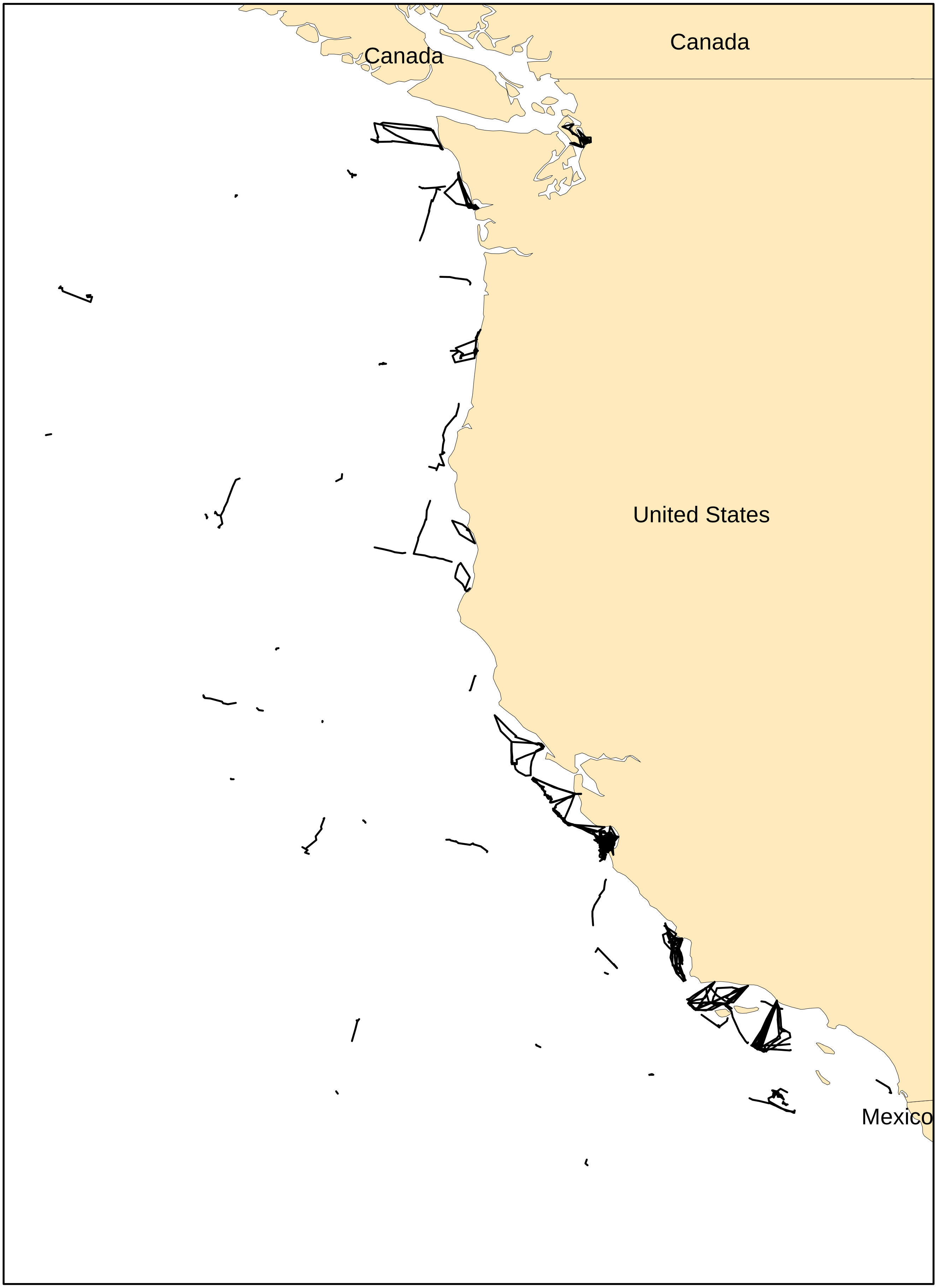

Figure 1. Survey effort for photographic identification conducted from small boats by Cascadia Research and collaborators in 2001.

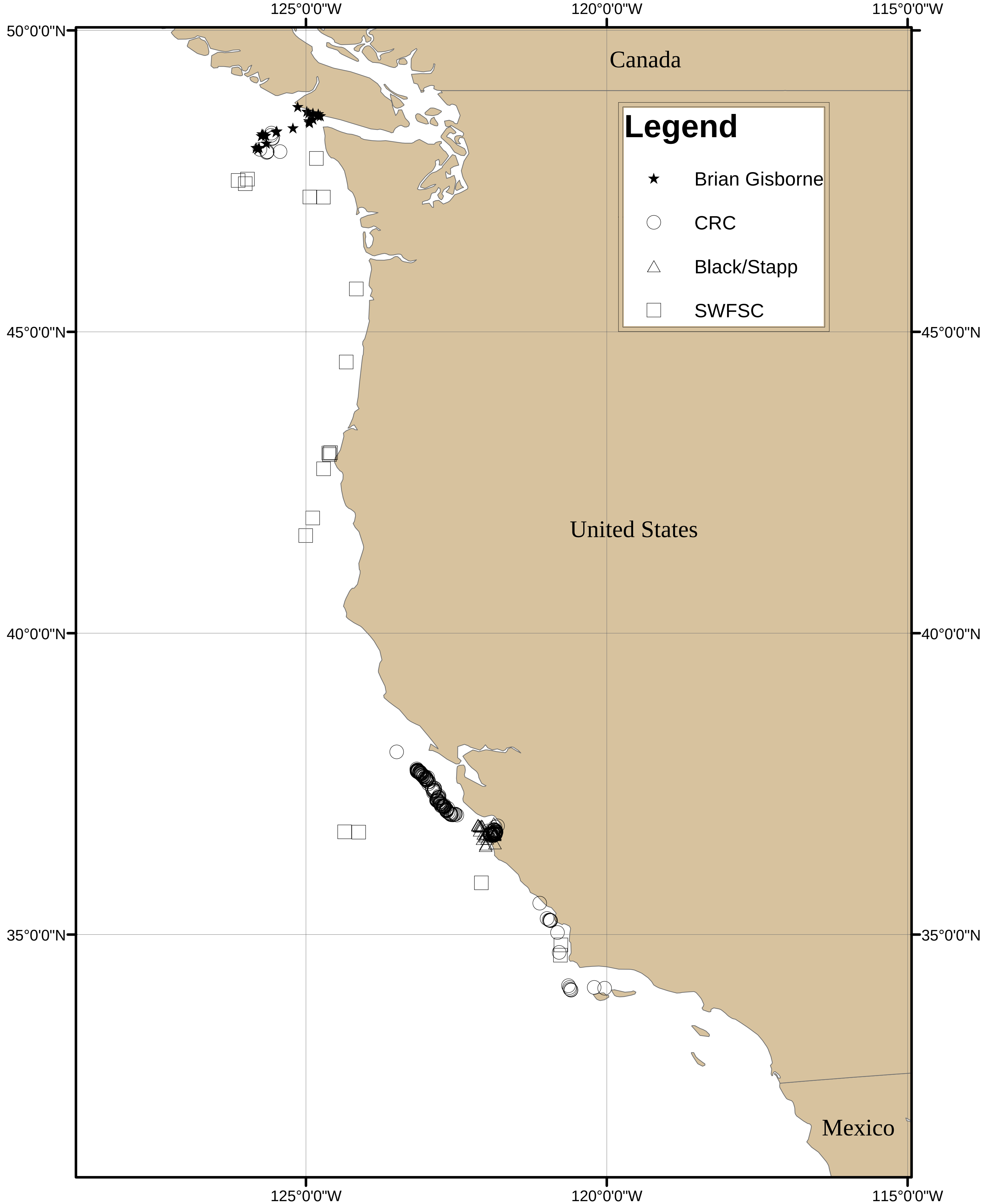

Figure 2. Locations humpback whales were photographically identified off California, Oregon, and Washington in 2001.

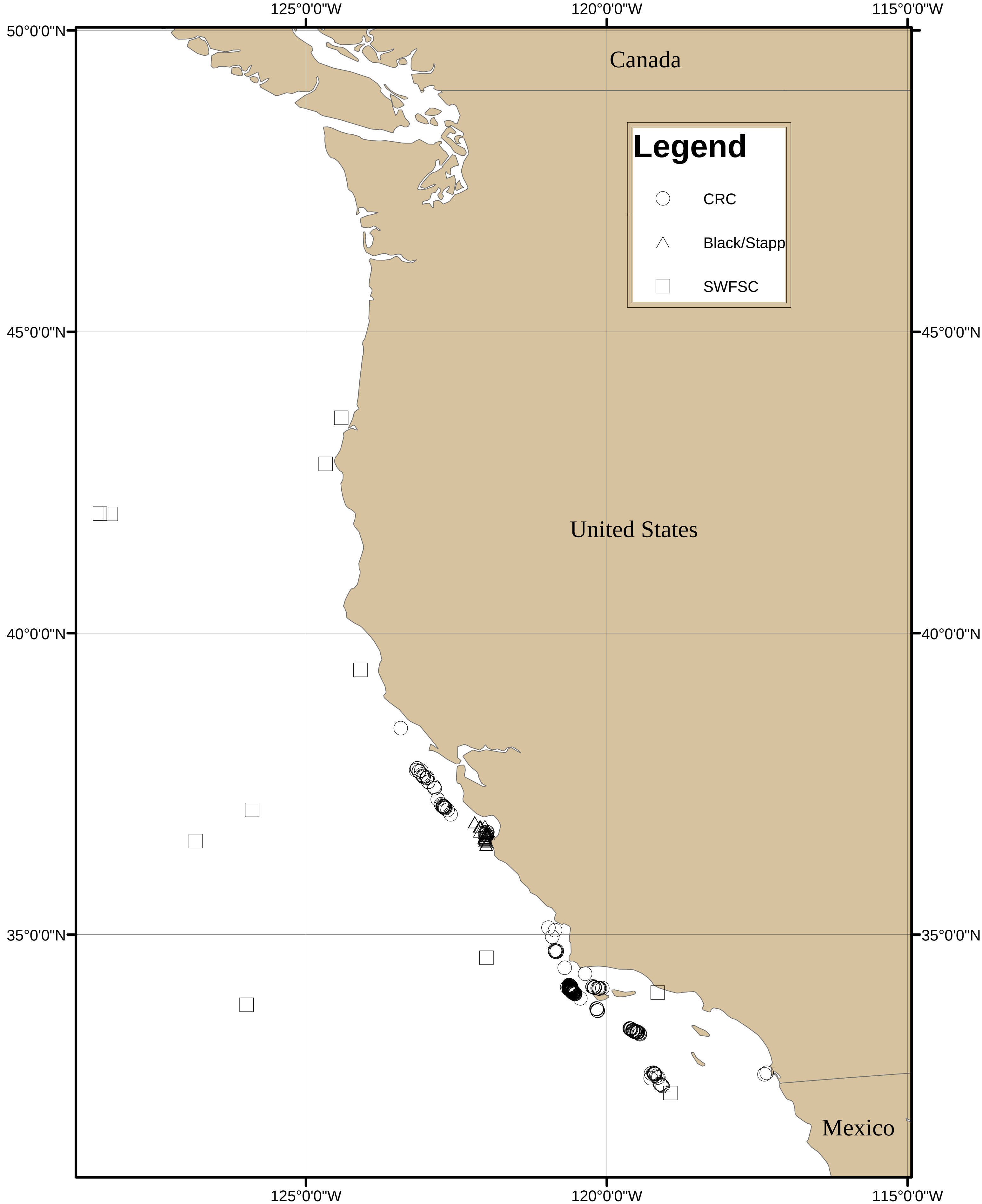

Figure 3. Locations blue whales were photographically identified off California, Oregon, and Washington in 2001.

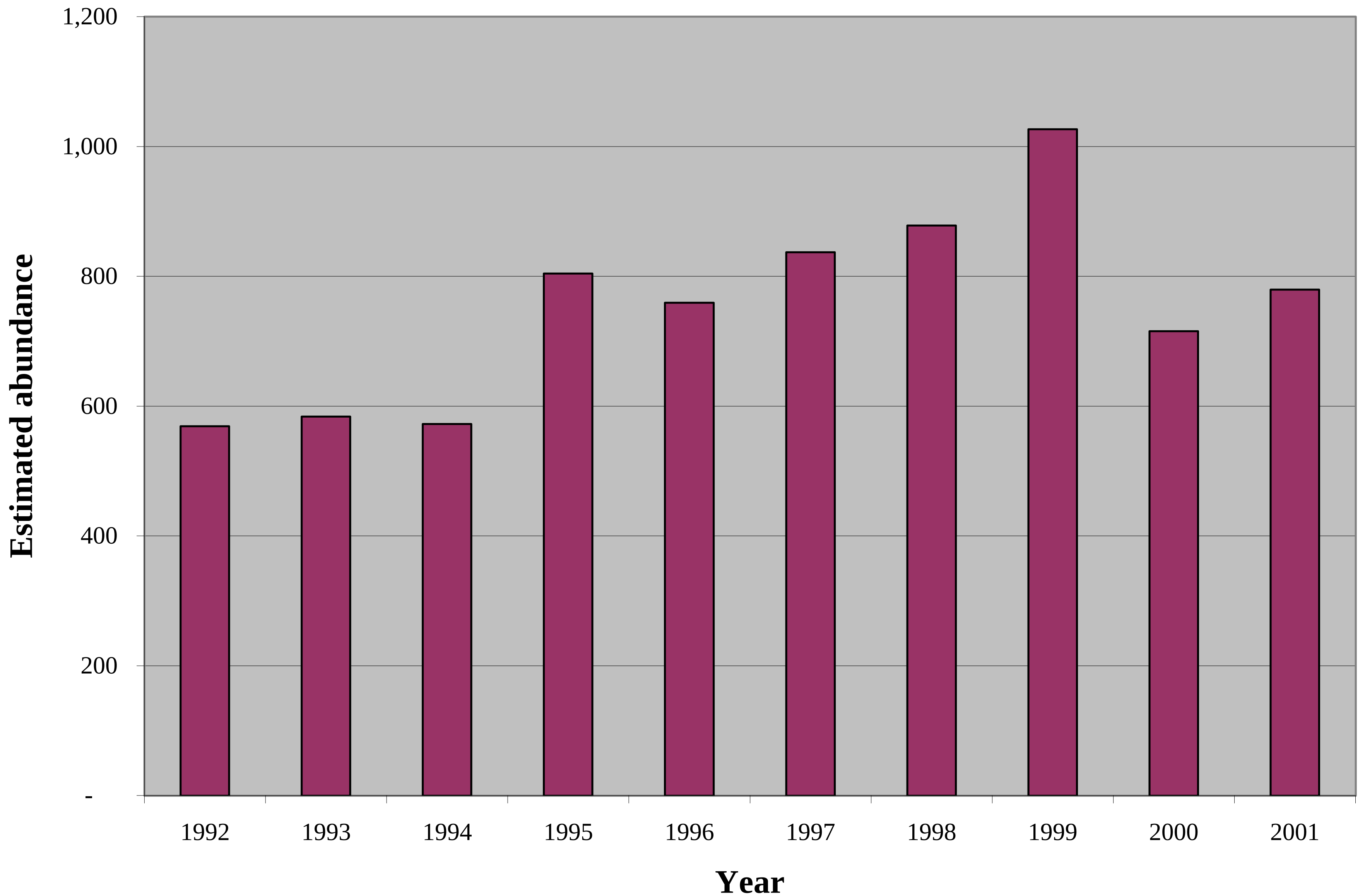

Figure 4. Trends in humpback whale abundance based on inter-year Petersen estimates.

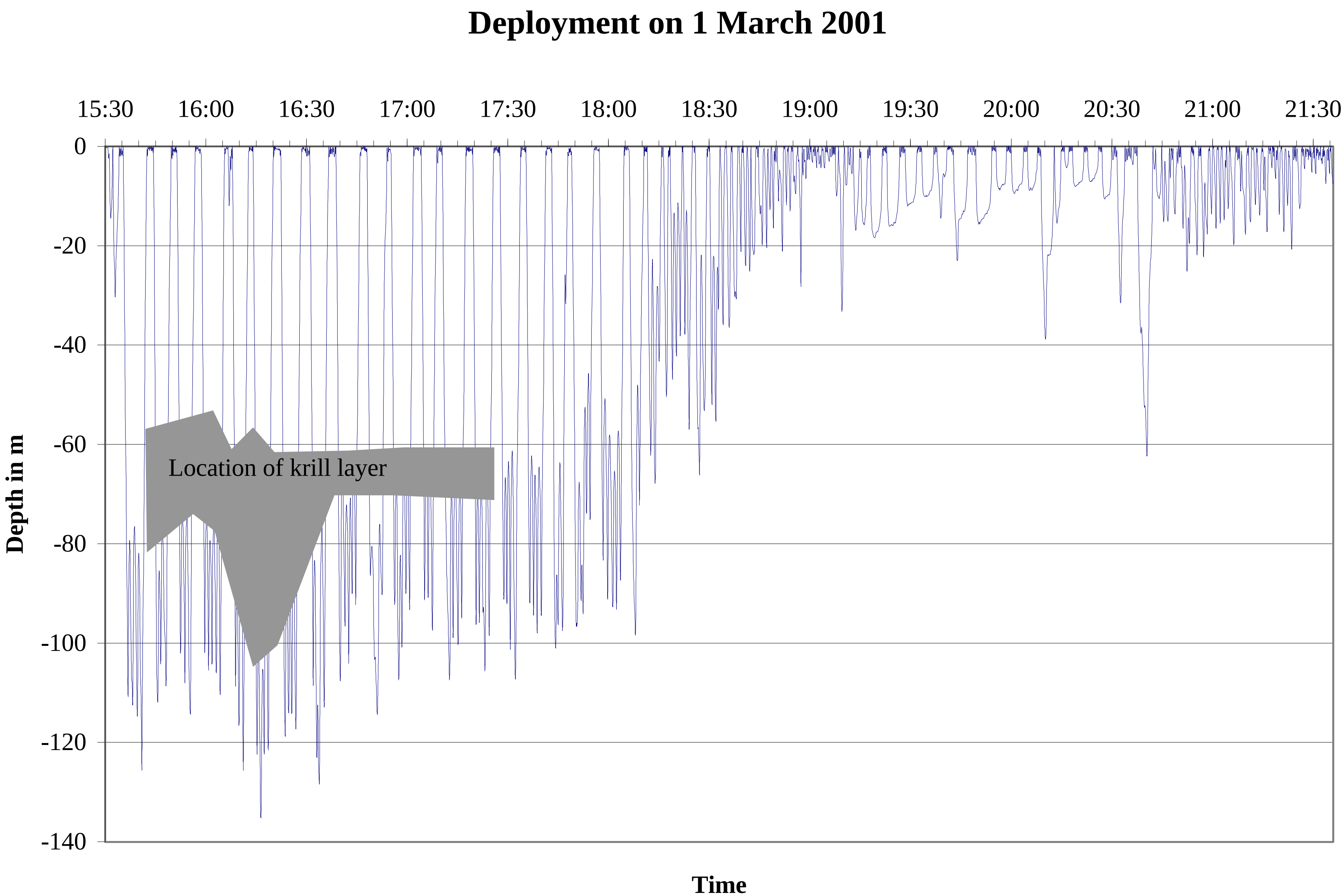

Figure 5. Dive behavior of blue whale tagged on 1 March 2001 in the Sea of Cortez. Krill layer from depth sounder readings taken in footprint of whale.

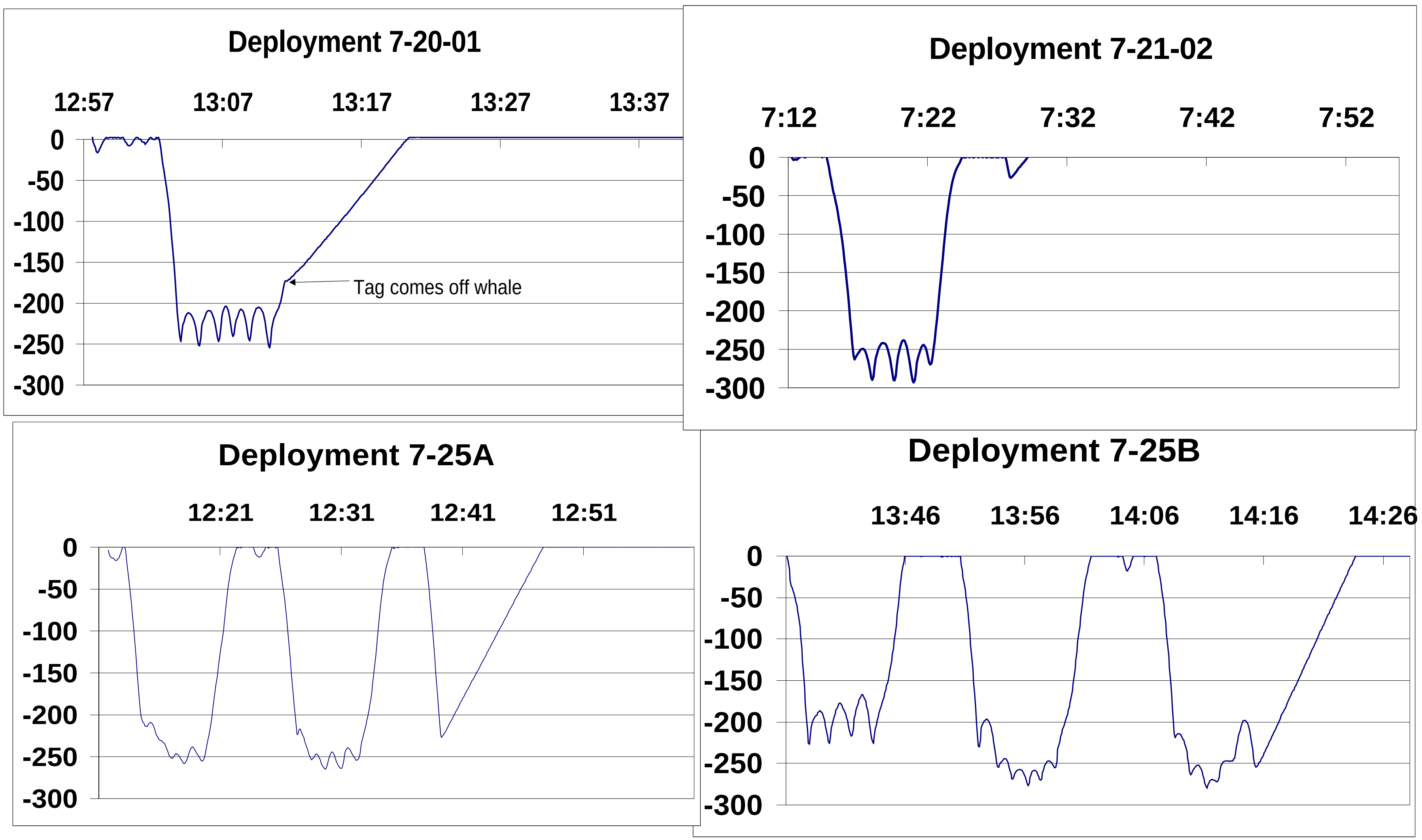

Figure 6. Sample dives from Crittercam deployments 20-25 July in the S California Bight.